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COMMERCIAL PRODUCTION OF TABLE WINES

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CONTENTS

	PAGE
Introduction	3
Statistics on production and consumption	5
Nature and composition of wines	8
Definition of wine	8
Composition of table wines	9
Federal and state restrictions	14
Grapes for table-wine making	16
Composition	16
Recommended grape varieties	26
Alcoholic fermentation	29
Nature of fermentation	29
Effect of environmental conditions	31
Propagation of fermentation	35
Control of undesirable organisms	35
Balancing the must	35
Stuck wines	37
Stabilization of wine by removal of nutrients	39
Use of sulfur dioxide	39
The use of pure yeasts	45
Control of temperature	48
Winery design, construction, and sanitation	53
Design and construction	53
Equipment	55
Winery sanitation and operation	63
Directions for making red and pink table wines	66
Harvesting and transportation of grapes for red wines	66
Wine-making procedure for red wines	67
Aging of red table wines	74
Pink wines	76
Directions for making dry white table wines	78
Harvesting and transportation of grapes for dry white wines	78
Wine-making procedure for dry white wines	78
Aging of dry white table wines	82
Directions for making natural sweet table wines	84
Harvesting and transportation of grapes for natural sweet wines	84
Wine-making procedure for natural sweet wines	85
Aging of natural sweet wines	87
Miscellaneous types	88
Development of wine	89
After fermentation	89
Effect of aging	89
Fining	92
Filtration	94
Centrifuging	96
Pasteurization	96
Champagne and other sparkling types of wine	97
Definition	97
The still-wine base	98
The secondary fermentation in glass	99
Fermentation in large-sized tanks	103
Carbonation	103
Corking and capping	103
Aging and storage	104
Preparation for market	104
Tasting	104
Microscopic examination	105
Analysis	106
Blending	108
Bottling	109
Labeling	112
Winery by-products	118
Pomace	118
Cream of tartar	119
Spirits	120
Stabilization of wine	120
Appearance	120
Bacterial spoilage	120
Wine disorders caused by oxidation or reduction	123
Acknowledgments	128
Selected references for further reading	129
Index	139

COMMERCIAL PRODUCTION OF TABLE WINES[1, 2]

M. A. AMERINE[3] AND M. A. JOSLYN[4]

INTRODUCTION

THE COMMERCIAL PRODUCTION of table wines—those containing not over 14 per cent alcohol—is discussed in this bulletin. Included are still wines produced by natural fermentation (partial or complete) and champagne and other types of sparkling wines. These are now known in the industry as "table wines" because they are served with various appropriate courses at dinner; they are also referred to as "light," "natural," "dinner," and often as "dry" wines. But "dry," and likewise the term "sweet" for wines containing over 14 per cent alcohol, have proved confusing because the so-called "dry" wines are sometimes sweet to the taste and the "sweet" wines sometimes dry; these terms have therefore been rejected for legal use and are being discouraged by the industry. Wines containing over 14 per cent alcohol, produced by the addition of small quantities of brandy during or after fermentation for the purpose of retaining some natural grape sugar in the wine, are now called "dessert and appetizer wines." Since these present very different problems to the wine maker, they will be discussed in a separate bulletin.

Methods are given in this bulletin for producing, in California, both ordinary table wines (basically clean, sound wines of standard quality) and fine table wines (those of choice, or fancy, quality). Ordinary wine, known in France as "vin ordinaire," supplies most of the consumption in the great wine-producing countries, where it is made by simple, natural, and inexpensive methods; it is usually not aged but consumed within a year after fermentation. The fine wines make up a small part of the world production, are made with great care from selected grapes, and are frequently aged for considerable periods; they are the high-priced wines upon which a reputation for quality in wine making is built. The large-scale equipment and bulk handling recommended for ordinary wines are usually not desirable or satisfactory for the fine wines.

Methods of producing ordinary wines under present conditions have been fairly well worked out, but there remains the problem of improv-

[1] Received for publication September 28, 1939.

[2] This bulletin supersedes Agricultural Extension Circular 88, *Elements of Wine Making*, by M. A. Joslyn and W. V. Cruess, published in 1934.

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ing the quality (color, flavor, bouquet), in order to build up the reputation of the California industry.

The quality desired may be partially obtained by the proper use of the better varieties of wine grapes. In most districts, there is a shortage

TABLE 1

CALIFORNIA ACREAGE OF GRAPES BY CLASSES AND WINE GRAPES BY VARIETIES, 1938

Class and variety	Total acreage bearing and nonbearing,* 1938	Acreage planted in years 1933-1938 and standing in 1938	
		Acreage	Per cent of total of variety or class†
	1	*2*	*3*
	acres	*acres*	*per cent*
All varieties	510,038	53,777	10.5
Table varieties	84,691	9,188	10.8
Raisin varieties, total	249,754	28,579	11.4
Muscats	65,027	1,601	2.5
Wine varieties, total	175,593	16,010	9.1
Red wine varieties, total	160,608	11,184	7.0
Zinfandel	53,741	4,052	7.5
Carignane	31,196	1,967	6.3
Alicante Bouschet	29,884	416	1.4
Mission	10,837	1,131	10.4
Mataro	8,247	349	4.2
Petite Sirah	7,720	573	7.4
Grenache	3,213	478	14.9
Others	15,770	2,218	14.1
White wine varieties, total	14,985	4,826	32.2
Palomino (Golden Chasselas)	3,587	1,780	49.6
Burger	2,888	600	20.8
Sauvignon vert (Colombard)	1,572	392	24.9
Sylvaner (Franken Riesling)	512	99	19.3
Others	6,426	1,955	30.4

* Estimated nonbearing acreage of grapes by variety classes in California in 1939 as a percentage of the corresponding acreage of all ages was approximately as follows: raisin varieties, 5 per cent; table varieties, 7 per cent; wine varieties, 3.5 per cent; and all varieties, nearly 5 per cent.

† Per cent of corresponding item in col. 1.

Sources of data:

Compiled by S. W. Shear, Giannini Foundation of Agricultural Economics, College of Agriculture, University of California, from: Blair, R. E., and H. C. Phillips. Acreage estimates of California fruit and nut crops as of 1938. p. 24 and 25. California Cooperative Crop Reporting Service. July 1, 1939.

of the varieties of wine grapes best suited to the climatic and soil conditions and to the types of wine made. New plantings of the varieties of wine grapes recognized for their high quality are rather limited (table 1); while red wine grapes such as Zinfandel, Carignane, and Alicante Bouschet which produce only ordinary wine predominate. Any improvement in this direction rests with the grape grower, of course, but the wine maker could probably do much to encourage the production of finer and better-adapted varieties in his district, particularly by insisting on the best grapes for his higher-quality wines and also by compensating the grower adequately for the low-production, quality varieties.

The unusually favorable soil and climate of California offer great opportunities for the profitable development of characteristic native wines, though only a few such types have been produced thus far. The industry in general has neglected the opportunities in this field and has catered to the trade demand for foreign wine types. The absence of sharply defined, well understood, and well enforced standards for foreign types, whether produced here or abroad, has resulted in confusing arrays of widely differing wines under the existing type labels. Standardization of wine types is necessary since at present there is too great a variation in both composition and flavor of the same type of wine as produced at different wineries. With the hope of promoting such standardization, suggestions on the preferred usage of various common type labels have been made in this bulletin.

The material included here is based upon observations in the field, upon the available scientific and technological literature, and upon the results obtained during the past five years by the Division of Viticulture on the viticultural and enological aspects of wine making, and by the Division of Fruit Products on the chemical, technological, and microbiological aspects.

The principles involved in wine making are discussed in some detail because a thorough understanding of them is essential to the wine maker who wishes to improve present methods or create distinctive California types. Still further details, both on principles and practice, may be found in the references listed by subject at the back of the bulletin. Those who are interested only in practical directions for wine making may turn to page 66; those interested in only certain phases of the subject may find the sections they wish by consulting the table of contents or the index.

STATISTICS ON PRODUCTION AND CONSUMPTION

The existing data[5] on consumption and production of wine are given in tables 2 and 3.

The 1938 per-capita consumption of commercial wine in California, 3.14 gallons, is considerably higher than that in the other states—0.41—or that in the United States as a whole—0.54—but is small in

[5] For statistical data and analyses see: United States Tariff Commission, Grapes, raisins, and wines. U. S. Tariff Comm. Rept. 134, 2d series. 408 p. U. S. Government Printing Office, Washington, D. C., 1939.

See also annual statistical numbers of the *Wine Review* and current bulletins of the Wine Institute.

TABLE 2

UNITED STATES APPARENT CONSUMPTION OF STILL WINE, YEARS BEGINNING JULY 1, 1933–1939

Year beginning July 1	United States*						California			Other states		
	Total		Dessert and appetizer, over 14 per cent alcohol	Table, not over 14 per cent alcohol								
	Commercial and homemade	Commercial		Total	Commercial	Homemade	Total	Commercial	Homemade	Total	Commercial	Homemade
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
	Total consumption in thousands of gallons (that is, 000 omitted)											
1933	52,146	17,526	10,973	41,173	6,553	34,620	13,010	8,000†	5,010	39,136	9,526	29,610
1934	70,916	37,856	24,491	46,425	13,365	33,060	21,650	17,600†	4,050	49,266	20,256	29,010
1935	86,027	50,012	32,958	53,069	17,054	36,015	23,957	21,152	2,805	62,070	28,860	33,210
1936	95,338	65,503	42,775	52,563	22,728	29,835	23,942	20,897	3,045	71,396	44,606	26,790
1937	98,895	64,230	41,350	57,545	22,880	34,665	21,523	19,828	1,695	77,372	44,402	32,970
1938	99,746	70,526	46,490	53,256	24,036	29,220	22,340	19,760	2,580	77,406	50,766	26,640
1939	—	—‡	—‡	—	—‡	31,275§	—	—‡	1,740§	—	—	29,535§
	Per-capita consumption in gallons											
1933	0.41	0.14	0.09	0.32	0.05	0.27	2.20	1.35	0.85	0.33	0.08	0.25
1934	.56	.30	.19	.37	.11	.26	3.63	2.95	.68	.41	.17	.24
1935	.67	.39	.26	.41	.13	.28	3.97	3.51	.46	.51	.24	.27
1936	.74	.51	.33	.41	.18	.23	3.92	3.42	.50	.58	.36	.22
1937	.76	.49	.32	.44	.17	.27	3.47	3.20	.27	.63	.36	.27
1938	0.76	0.54	0.36	0.40	0.18	.22	3.55	3.14	.41	0.62	0.41	.21
1939	—	—	—	—	—	0.24§	—	—	0.27§	—	—	0.24§

* Includes average imports, 1933-1938, of 2,941,000 gals. or 3.5 per cent of consumption, about half table wine and half dessert and appetizer.

† Estimates by S. W. Shear.

‡ U. S. tax-paid domestic withdrawals July-December, 1939, were 14 per cent greater than July-December, 1938, for all still wine, 17 per cent greater for dessert and appetizer wine, 8 per cent greater for table wine, while California commercial consumption was 3 per cent less.

§ Preliminary estimates.

Sources of data:

Compiled in: Shear, S. W. Deciduous fruit statistics as of January, 1940. Univ. California Giannini Foundation Mimeo. Rept. **69**:60. 1940.

Cols. 1, 2, 4, 7, and 10: Calculated by addition.

Cols. 3 and 5: Sum of domestic tax-paid withdrawals, Bureau Internal Revenue, and U. S imports.

Cols. 6 and 9: Homemade or basement wine from estimate of California grapes so used, at 150 gallons per ton, with no estimates of basement wine made from grapes produced outside of California. Very little homemade wine was consumed before Prohibition. U. S. per-capita consumption of commercial wine 1909–1913 averaged about 0.5 gallons of which 0.2 was dessert and appetizer and 0.3 table.

Col. 8: Based on Wine Institute, Wine Industry Statistical Survey reports, mimeographed.

Cols. 11 and 12: Calculated by subtracting California data from U. S. data.

TABLE 3

United States and California Production, Stocks, Supply, and Disappearance of Commercial Still Wine, Average 1909–1913, and Annual 1933–1939

Year beginning July 1	Stocks, July 1			Net finished production			Total supply			Disappearance		
	Total	Dessert and appetizer, over 14 per cent alcohol	Table, not over 14 per cent alcohol	Total	Dessert and appetizer, over 14 per cent alcohol	Table, not over 14 per cent alcohol	Total	Dessert and appetizer, over 14 per cent alcohol	Table, not over 14 per cent alcohol	Total	Dessert and appetizer, over 14 per cent alcohol	Table, not over 14 per cent alcohol
	1	2	3	4	5	6	7	8	9	10	11	12
United States, in thousands of gallons (that is, 000 omitted)												
Average: 1909–1913	—	—	—	52,924	20,074	32,850*	—	—	—	49,445	19,198	30,247*
Annual:												
1933	25,542	11,597	13,945	39,239	17,583	21,656	64,781	29,180	35,601	14,613	9,516	5,097
1934	50,168	19,664	30,504	41,980	27,311	14,669	92,148	46,975	45,173	35,671	23,396	12,275
1935	56,477	23,579	32,898	69,821	55,363	14,458	126,298	78,942	47,356	47,826	31,855	15,971
1936	78,472	47,087	31,385	52,031	36,490	15,541	130,503	83,577	46,926	62,395	41,208	21,187
1937	68,108	42,369	25,739	95,308	59,416	35,892	163,416	101,785	61,631	61,399	39,920	21,479
1938	102,017	61,865	40,152	60,392	38,316	22,076	162,409	100,181	62,228	67,567	44,989	22,578
1939†	94,842	55,192	39,650	80,000†	57,000†	23,000†	174,842	112,192	62,650	—	—	—
California, in thousands of gallons (that is, 000 omitted)												
Average: 1909–1913	—	—	—	43,595	19,161	24,434*	—	—	—	—	—	—
Annual:												
1933	22,620	10,351	12,269	35,679	16,052	19,627	58,299	26,403	31,896	12,974	8,640	4,334
1934	45,325	17,763	27,562	37,005	25,928	11,077	82,330	43,691	38,639	34,944	23,366	11,578
1935	47,386	20,325	27,061	65,690	54,013	11,677	113,076	74,338	38,738	45,206	31,696	13,510
1936	67,870	42,642	25,228	46,678	34,700	11,979	114,549	77,342	37,207	58,212	40,574	17,638
1937	56,337	36,768	19,569	85,351	57,302	28,049	141,688	94,070	47,618	54,363	38,718	15,645
1938	87,325	55,352	31,973	50,342	35,581	14,761	137,667	90,933	46,734	57,155	42,628	14,527
1939†	80,512	48,305	32,207	68,000†	53,000†	15,000†	148,512	101,305	47,207	—	—	—

* Data on champagne and other sparkling wines included for 1909-1913 but excluded for 1933-1939.

† Rough preliminary 1939 production estimates subject to considerable revision; based on data for July-December.

Sources of data:

Compiled in Shear, S. W. Deciduous fruit statistics as of January, 1940. Univ. California Giannini Foundation Mimeo. Rept. **69**:61. 1940.

Cols. 1-3: for 1933-1939 from reports of the Bureau of Internal Revenue.

Cols. 4-6 and 10-12: for 1909-1913, average from: Shear, S. W., and G. G. Pearce. Supply and price trends in the California wine-grape industry. Univ. California Giannini Foundation Mimeo. Rept. 34, tables 7, 9. 1934. For 1933-1939 based on data in reports of Bureau of Internal Revenue.

Cols. 7-12: for 1933-1939 calculated from data in cols. 1-6.

comparison with over 30 gallons in France, and 25 gallons in Italy. Wine consumption has increased in other states since 1934 particularly during 1939.

The commercial production of California wine in 1939 of about 68,000,000 gallons is definitely higher than that produced in 1938 but is less than that produced in the peak year of 1937. California produces over 80 per cent of the wine made in the United States. The total production of wine in the United States is small in comparison with the 6 billion gallons of world production. Production in Europe and French Africa combined accounts for over 90 per cent of the total output; French territory alone produces nearly half of the world total.

Although the bulk of the wines produced in the world are table wines, and in the pre-Prohibition era over half the total wines produced in California were table wines, the dessert and appetizer wines lead the production in this state at present. An increased consumption of wines of both classes is expected by the industry.

NATURE AND COMPOSITION OF WINES [6]

DEFINITION OF WINE

Wine is the product of the partial or complete fermentation of the juice of grapes. The California State Department of Public Health defines it as follows:

1. Wine is the product made by the normal alcoholic fermentation of the juice of sound ripe grapes, without addition or abstraction, other than pure grape products, except such as may occur in the usual cellar treatment or clarifying and aging, provided that the volatile acids and other constituents in the wine shall conform to the standards set by Federal and State of California regulations, except as otherwise provided herein.

2. Light wine, other than champagne, shall mean wine containing 14 per centum or less of alcohol by volume.

3. Sweet wines are wines which are fortified by the addition of grape brandy or grape spirits, and which may be sweetened by the addition of grape must or concentrate.[7]

The Federal Alcohol Administration of the United States Treasury Department gives the following definition:

Section 21, Class 1. *Grape wine.*—(a) "Grape wine" is produced by normal alcoholic fermentation of the juice of sound, ripe grapes (including restored or unrestored pure condensed grape must) with or without the addition, after fermentation, of pure condensed grape must, and with or without added fortifying grape spirits or alcohol, but without other addition or abstraction except as may occur in cellar treatment. . . .[8]

[6] General references on this subject are listed on page 130.

[7] California State Department of Public Health. Definitions and standards, wines; as approved to Dec. 1, 1938.

[8] United States Treasury Department, Federal Alcohol Administration, Regulations No. 4, relating to labeling and advertising of wines, as amended to March 1, 1939.

Although various government agencies have defined it in slightly different fashions, all indicate that wine is essentially a fermented alcoholic grape beverage.

Numerous types of wines are produced from many varieties of several *Vitis* species: ordinarily, in California, varieties of *Vitis vinifera* only are used. The juice of grapes varies in character, composition, and suitability for wine making, not only with the different varieties but also for the same variety grown under different environmental conditions and treated in different ways before, during, and after fermentation.

Wines which derive their alcohol entirely from their own fermentation are the province of this bulletin. Such wines may be sweet or dry (without sufficient sugar to taste), red or white, or still or sparkling. (Small amounts of brandy are added to some sparkling wines at the time of shipment.) They are the wines intended for consumption mainly during meals and are frequently spoken of as "table" wines. By far the greater portion of the wines of commerce of the world are of this type.

Wines which are produced by the addition of amounts of alcohol in addition to that derived from their own fermentation will be discussed in a later bulletin. They may be either dry or sweet, red or white (amber), but are always still. They are frequently spoken of as "dessert" or "appetizer" wines to indicate their predominate usage. At least 50 per cent of the wines produced in California are of this type.

The type names under which California wines are marketed are derived from foreign geographical names, from names of varieties of grapes, or from proprietary names or brands. Several types of the existing California table wines are not uniform because of the ambiguity of the current interpretation of type names of foreign geographical origin.

COMPOSITION OF TABLE WINES

Significance of Chemical Constituents.—Certain components of wines are useful in differentiating between the various classes, others in determining soundness (freedom from products of spoilage) and identity.

Under California conditions, the alcohol content of these wines does not differ markedly from type to type, since the climate is warm enough to mature practically all varieties of grapes. To comply with regulations, table wines must have between 11 and 14 per cent alcohol. The lighter types of table wines should have an alcohol content nearer the lower limit since such wines are usually fruitier and therefore more palatable.

The sugar content of the wine is a good indication of the completeness of fermentation. It is also useful in differentiating certain types of wines, such as sauterne types (p. 117). Wines with less than 0.2 per cent sugar are "dry," since this amount of sugar is barely, if at all, perceptible to the tongue. It is also low enough to prevent refermentation by the usual wine yeasts.

The extract content (soluble, non-sugar solids) distinguishes the heavy- and light-bodied types. Wines having an extract below 2 per cent are very light on the palate as compared with wines having one over 3. Before comparing the real extract contents of two different wines, the sugar content should be subtracted from the apparent extract. Full-bodied red table wines may have an extract content exceeding 3.0 but the dry, white table wines approach an average extract content of 2.0.

The volatile-acid content is a good indication of soundness. Wines with high volatile-acid content taste vinegary. Peynaud,[9,10] has recently shown, however, it is the ethyl acetate formed by acetic acid bacteria rather than the acetic acid itself that produces the objectionable, sharp, vinegary, or acescent taste in such wines. For identification of the nature, type, and objectionableness of the spoilage, undesirable volatile products of wines may best be determined separately.

The total acid (nonvolatile acids mainly) content is helpful in differentiating certain types. Wines of high total acid (over 0.80 per cent) taste fresh and tart, whereas those of low total acid (below 0.55) are flat and insipid. Natural sweet table wines should not be high in total acid since they will then have an undesirable sweet-sour taste. Likewise aged dry red and white table wines are better balanced with moderate acid contents. The low total-acid content of several of the dry-table-wine types is one of the most serious defects of California wines.

The tannins produce an astringent taste; a tannin content of over 0.20 per cent is indicative of a rather rough red wine. The darker-colored, heavier-bodied wines usually contain more tannin than the lighter-colored and lighter-bodied ones, although a few varieties (for example, Grignolino) are high in tannin but low in coloring matter. Young wines are higher in tannin content than old wines and one of the purposes of aging is to permit the astringency of the wines to be reduced by the precipitation of excess tannin. Wines of quality do not contain sufficient tannin to give an objectionable astringent taste.

The usual range of tannin content is 0.02 to 0.05 per cent for white table wines and 0.15 to 0.30 for red table wines. Wines containing much

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[9] Peynaud, E. Les phénomènes d'esterification dans les vins. Annales des Fermentations 3:242–52. 1937.

[10] Peynaud, E. L'acétate d'éthyle dans les vins atteints d'acescence. Annales des Fermentations 2:367–84. 1936.

over 0.20 per cent are usually too astringent and puckery but the method used for determining tannin content is too nonspecific to make any general recommendation. The type of tannin present, the age and composition of the wine, and the presence of nontannin permanganate-reducing matter all influence the palatability of a wine at a given "tannin" content.

Color determinations on white wines are seldom made, since all white wines gradually darken with age and since they may contain varying amounts of sulfur dioxide that tends to bleach them. The excessive use of sulfur dioxide tends to make the color of white wines too light. With red wines, color determinations are commonly made. These indicate directly the amount of color and assist in differentiating the types. In addition, certain instruments measure the tint, which is helpful in classification.

The dry white table wines should have a pale-yellow color, particularly in the Riesling and Chablis types. The white sweet table wines are slightly more yellow in color, but no white table wine should be amber in tint since this is a sign of overaging or of undesirable oxidation. The lightest-colored red table wines are the pink wines, which have a pale-rose color. The other types should be of a full-red color without too much blue or brown.

Wines having considerable glycerin are heavier-bodied and smoother than those containing little. Natural sweet wines should be fairly high in glycerin content in order to have the desirable smoothness in texture which a high glycerin content gives.

The ratios between the concentrations of certain components or between components determined in several ways are commonly used abroad to detect adulteration or abnormalities. These ratios have not been adapted to California conditions but should prove more useful than actual composition because for a particular natural wine they vary over a narrower range. The following ratios have been used:

1. Test for determining if a natural sweet wine has derived its sugar from the original must or has been made by adding must or concentrate to a dry wine.

Blarez ratio: $\frac{\text{Concentration of copper-reducing material}}{\text{Optical rotation}}$, an index characteristic of the proportion of dextrose and levulose present; usually below 4 for natural sweet wines.

2. Tests to determine if the wine is a normal or a natural one, that is, undiluted. In these ratios the acid is expressed as grams of sulfuric acid per liter. Multiply percentage acid as tartaric by 6.4 to convert to grams of sulfuric per liter. The volatile acid expressed as percentage acetic acid multiplied by 8.0 gives volatile acid as grams of sulfuric acid per liter. Total acid as grams of sulfuric acid per liter minus volatile acid as grams of sulfuric per liter gives fixed acid. Unless otherwise stated, all other

total-acid contents given in this bulletin are expressed as grams of tartaric acid per 100 cc of grape juice or wine.

a) Gautier sum: alcohol + total acid, characteristic of initial sugar content and acid content of the grapes. When the alcohol is expressed in percentage by volume and the acidity in grams of sulfuric acid per liter, this sum usually varies from 13 to 17 for undiluted French wines.

b) Halphen ratio: $\frac{\text{total acidity}}{\text{alcohol content}}$. Ratio found is compared with normal ratios for wines of the same type and alcohol content.

c) Blarez ratio: $\frac{\text{alcohol content}}{\text{fixed or nonvolatile acidity}}$. Ratios vary from 1 to 3, according to type and origin of the wine for low-alcohol French wines.

d) Extract ratio: $\frac{\text{alcohol content}}{\text{reduced extract}}$. Maximum is about 6.5 for dry, white table wines and 5.5 for dry red table wines. Extract minus sugar equals reduced extract.

e) Roos ratio: $\frac{\text{alcohol} + \text{fixed acidity}}{\text{ratio alcohol : reduced extract}}$. Usually is over 3.1 for red wines and 2.4 for white wines.

f) Glycerin ratio: $\frac{\text{alcohol content}}{\text{glycerin content}}$. When the alcohol and glycerin are expressed in percentage by weight, normal California wines should not have ratios below 5.5. For French wines the minimum value is 7.0.

A summary of the composition of the more important types of wines to be discussed in this bulletin is given in table 4. Data for pre- and post-Prohibition California wines as well as for their foreign prototypes are given. Additional data on the composition of California wines will be found in a later section on the labeling of wines (p. 112).

Importance of Subjective Factors.—Unfortunately, several of the constituents that characterize a wine type cannot be estimated easily by chemical analysis. The flavoring matters and the aroma- and bouquet-contributing substances, at present measured subjectively by tasting, are present in small amounts. No doubt as better methods are discovered and new, distinctive components are differentiated, more rigid standards for the different types of wines, based on the quantitative determination of these substances, will be developed.

The most obvious and distinctive flavoring constituents are those that give the wine its varietal character—for example, Muscat, Zinfandel, or Cabernet. Some of these aromatic principles are readily detectable, others faint. The problem of their chemical detection and quantitative measurement is complicated not only by the minute quantities present but also by their susceptibility to oxidation and by the subsequent changes that they undergo in aging. As the California wine industry develops, greater emphasis will probably be given to the production of wines having distinctive varietal characteristics.

TABLE 4

Comparison of the Composition of Types of California Table Wines before and after Prohibition and Some Similar European Types

Wine type	Number of samples	Total acid as tartaric		Volatile acid as acetic		Alcohol		Extract		Sugar		Tannin and coloring matter		Total sulfur dioxide*	
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
		grams per 100 cc	*grams per 100 cc*	*grams per 100 cc*	*grams per 100 cc*	*per cent*	*per cent*	*grams per 100 cc*	*grams per 100cc*	*grams per 100 cc*	*grams per 100cc*	*grams per 100 cc*	*grams per 100cc*	*parts per million*	*parts per mil'n*
California Chablis:															
Pre-Prohibition[a, b]	7	0.49–0.67	0.57	...	0.104[c]	10.6–12.8	12.1	1.8–2.2	2.1	0.10–0.45	0.21	0.03–0.06	0.04	...	..
Post-Prohibition[d]	31	0.42–0.73	0.56	0.045–0.124	0.088	10.2–12.9	11.9	1.9–3.0	2.5	0.09–0.42	0.19	0.02–0.08	0.05	13–360	149†
Chablis (French)[e]	9	0.34–0.74	0.60	0.038–0.112	0.069	9.4–13.4	11.4	1.8–2.9	2.2	0.05–0.86	0.24	...	..	...	..
California Riesling:															
Pre-Prohibition[a, b]	24	0.47–0.73	0.58	0.093–0.174[c]	0.134[c]	10.5–14.5	12.7	1.6–2.6	2.0	0.05–0.63	0.14	0.02–0.08[c]	0.04[c]	...	..
Post-Prohibition[d]	35	0.40–0.69	0.56	0.040–0.178	0.092	11.0–14.2	12.2	2.1–2.9	2.5	0.11–0.28	0.18	0.03–0.09	0.05	110–260	201†
Riesling (Rhine)[f]	68	0.36–1.62	0.77	0.020–0.080	0.050	5.9–13.1	10.1	2.0–5.3	2.9	0.01–0.83	0.23	...	..	0–255	50
Riesling (Moselle)[f]	187	0.46–1.46	0.77	0.020–0.140	0.050	5.4–12.1	9.2	1.6–4.6	2.3	0.04–1.11	0.20	...	..	...	..
California Haut Sauterne:															
Pre-Prohibition[a]	9	0.42–0.63	0.54	...	..	11.6–14.7	12.8	1.9–4.0	2.9	0.17–1.75	0.83	0.03–0.06	0.05	...	..
Post-Prohibition[d]	29	0.39–0.96	0.60	0.068–0.140	0.092	10.1–14.5	12.4	2.2–7.6	5.2	0.14–5.46	3.05	0.03–0.11	0.06	77–500	280†
Sauternes (French)[f]	11	0.65–1.28	0.81	0.066–0.159	0.114	9.8–15.4	12.9	2.3–12.8	5.1	0.65–8.27	3.33	...	..	133–468	235
California claret:															
Pre-Prohibition[a, b]	20	0.60–0.82	0.67	0.088–0.139[c]	0.115[c]	11.5–14.1	12.6	2.1–3.3	2.7	0.04–0.63	0.16	0.15–0.29	0.21	...	..
Post-Prohibition[d]	39	0.45–0.78	0.64	0.064–0.176	0.102	11.3–16.0	12.4‡	2.4–7.2	2.9‡	0.09–5.00	0.25‡	0.12–0.30	0.20	0–249	62
Claret (Médoc)[f]	40	0.38–0.68	0.58	0.092–0.106§	0.098§	8.4–11.6	10.2	2.0–3.9	2.4	0.11–0.84	0.23	...	..	...	..
California Burgundy:															
Pre-Prohibition[a, b]	20	0.58–0.78	0.69	...	0.109[c]	9.7–14.1	12.6	2.1–3.5	2.8	0.03–0.42	0.14	0.03–0.33	0.21	...	..
Post-Prohibition[d]	48	0.46–0.88	0.65	0.056–0.174	0.099	10.8–13.6	12.6	2.1–4.4	2.9	0.12–1.90	0.30	0.13–0.37	0.23	10–93	56
Burgundy (French)[f, g, h]	15	0.50–1.30	0.75	0.072–0.160	0.096	7.1–15.8	11.4	1.6–2.9[i]	2.1[i]	0.15–0.23	0.18	...	..	...	..
California red Chianti:															
Pre-Prohibition[a, b]	2	...	0.71	...	0.118	...	11.9	...	2.6	...	0.15	...	0.26	...	..
Post-Prohibition[d]	13	0.63–0.79	0.69	0.080–0.136	0.106	9.3–13.5	12.1	2.3–3.4	2.8	0.27–1.13	0.33	0.15–0.32	0.22	...	..
Chianti (Italian)[j]	29	0.56–0.79	0.65	0.049–0.101	0.071	11.1–14.1	12.5	2.2–3.1	2.5	...	..	0.09–0.30	0.20	...	..

* Post-Prohibition California sulfur dioxide analyses from 1939 Golden Gate International Exposition wines.

† Free sulfur dioxide content averaged 14, 13, and 70 parts per million in the Chablis, Riesling, and sauterne, respectively.

‡ Average does not include highest value.

§ Five samples only.

Sources of data:

[a] Bigelow, W. C. The composition of American wines. U. S. Dept. Agr. Div. of Chem. Bul. **59**: 1-76. 1900.

[b] Wiley, H. W. American wines at the Paris Exposition of 1900; their composition and character. U. S. Dept. Agr. Bur. of Chem. Bul. **72**:1-40. 1903.

[c] Analysis of H. W. Wiley only.

[d] Amerine, M. A. Unpublished data from 1937 and 1938 California State Fairs.

[e] Filaudeau, G. Les vins de l'Yonne de la Récolte 1911. Annales des Falsifications et des Fraudes. **5**:230–36. 1912.

[f] König, J. Chemische Zusammensetzung der menschlichen Nahrungs- und Genussmittel. vol. 1, 1535p. J. Springer, Berlin, 1903.

[g] Filaudeau, G. Les vins de la Récolte 1911. Annales des Falsifications et des Fraudes. **5**:36–44. 1912.

[h] Filaudeau, G. Resumé de l'enquête annuelle sur la composition des vins de consummation courante. Annales des Falsifications et des Fraudes. **9**:347–413. 1916.

[i] Curtel, M. L'Extrait sec des vins rouges de Bourgogne. Annales des Falsifications et des Fraudes. **5**:33–35. 1912.

[j] Anonymous. Per la tutela del vino Chianti e degli altri vini Tipici Toscani. 537p. Tipografia Antonio Brunelli, Bologna. 1932.

FEDERAL AND STATE RESTRICTIONS

The regulations of the various state and federal agencies concerning the names and composition of wines are complex and are changing constantly. Those interested in bonding a winery premise, securing the necessary permits, and producing wines should consult the Wine Institute, 85 Second Street, San Francisco, or the following government agencies: Basic Permit and Trade Practice Division of the Alcohol Tax Unit of the Bureau of Internal Revenue, United States Treasury Department; or Department of Public Health, Board of Equalization, or Department of Agriculture of the State of California. An outline of the pertinent restrictions is presented here.

Federal Regulations.—The most important restrictions on the composition and character of wines are found in Regulations No. 4 of the Federal Alcohol Administration, United States Treasury Department, regarding labeling and advertising. These regulations define wines and limit their composition as follows: for natural red wine, a maximum volatile acidity (calculated as acetic acid and exclusive of sulfur dioxide) of 0.14 gram per 100 cc; for other wines, a maximum of 0.12 gram per 100 cc. Red wine is defined as grape wine that contains the red coloring matter of the skins, juice, or pulp, whereas white wine contains no such red coloring matter.

Wines named for a specific variety of grape must derive from it at least 51 per cent of their volume and predominant taste, aroma, and characteristics. Wines with a specific appellation of origin must derive 75 per cent of their volume from grapes grown in the district and must be fermented and conform to the regulations of the district after which they are named. Generic and semigeneric designations for wines are also defined. Wines with a semigeneric name such as Burgundy, claret, Chablis, champagne, Chianti, Moselle, Rhine wine (syn. hock), and sauterne must have the actual district of origin stated in conjunction with the type on the label—for example, *California* claret.

Numerous labeling requirements are set up concerning mandatory information, such as brand name, type, name and address, blends, alcohol content, and contents. Regulations concerning dates and prohibited statements are also outlined. The age of bottled wine can be specified only if certain conditions are met.

Finished wines, without special labeling, should not have over 350 parts per million of sulfur dioxide (not more than 70 parts being in a free state). The rules also indicate that filtration, pasteurization, refrigeration, and other treatments should be used to the minimum extent necessary to stabilize the wine.

The regulations of the Food and Drug Administration largely define wine and specify limits for the content of certain constituents, such as acids, sugar, sodium chloride, potassium sulfate, and sugar-free solids. The present minimum limit for the last is far lower than that encountered in California.

The Bureau of Internal Revenue regulations, framed from the standpoint of revenue protection, embrace certain limitations in processing methods on bonded winery premises. Federal law and regulations define many operations which are permitted on bonded winery premises, but which are prohibited on wholesale or retail premises.

TABLE 5

LIMITS FOR CERTAIN CONSTITUENTS SET BY THE CALIFORNIA STATE DEPARTMENT OF PUBLIC HEALTH

	Dry red wine	Dry white wine
Alcohol	11 to 14 per cent	11 to 14 per cent
Volatile acid, calculated as acetic acid	0.12 grams per 100 cc maximum	0.11 grams per 100 cc maximum
Total acid, calculated as tartaric acid	0.40 grams per 100 cc minimum	0.30 grams per 100 cc minimum

State Regulations.—The Department of Public Health of the State of California has also set up certain restrictions establishing a minimum standard for wines in order to prevent poor, unsound wines from being offered to the consuming public, to protect the wine industry as a whole, and to induce better wine making. These are summarized in table 5. Besides meeting the requirements for chemical composition, the wines sold must be of a clean, vinous taste, free of "mold, mousiness, tourne, or lactic fermentation." Tartaric acid produced from grapes and commercial malic or citric acids are permitted for correcting deficient acidity, but only grape must or grape concentrate may be used to sweeten musts or wines. Pomace wines must be labeled "Imitation Wine." Recently proposals have been made to reduce the minimum alcohol requirement and to increase the minimum total-acid limit to 0.5 grams for the dry red wines and to 0.45 grams for the dry white wines. These would be desirable changes.

Under the California law, any wine labeled "California Central Coast Counties Dry Wine" must be produced 100 per cent from grapes grown in any one or more of the central-coast counties (Sonoma, Napa, Mendocino, Lake, Santa Clara, Santa Cruz, Alameda, San Benito, Solano, San Luis Obispo, Contra Costa, Monterey, and Marin).

GRAPES FOR TABLE-WINE MAKING [11]

COMPOSITION

To obtain wines of quality, the grapes must have the proper composition and character for the type; the fermentation must be sound, and appropriate for bringing out and accenting the flavor obtainable; and the aging process must be suitable. Without the adequate interrelation of these factors, a wine cannot develop quality.

The basis for many types is a particular variety of grape; the raw material for all table wine is sound, mature, fresh grapes. (But certain types of natural sweet wines are made from partially dried grapes.) The fine wines are made from grapes of a recognizable and distinct flavor.

TABLE 6

CHANGES IN THE WEIGHT OF THE STEMS, SKINS, PULP, AND SEEDS OF PETITE VERDOT GRAPES DURING MATURATION

	July 20	August 7	August 23	September 6	September 25
	grams	*grams*	*grams*	*grams*	*grams*
Average weight of stems......	2.5	2.3	3.1	2.7	2.1
Weight per 100 berries:					
Skins......................	5.9	6.4	6.6	7.7	11.0
Pulp.......................	31.6	47.9	58.3	64.4	118.5
Seeds......................	5.5	6.7	7.1	6.6	5.5
Average weight per berry.....	0.43	0.61	0.72	0.79	1.35

Source of data:
Laborde, J. Cours d'oenologie. Tome I, p. 7. Feret et Fils, Bordeaux. 1907.

Not all grapes produce such wines, but many varieties without distinctive flavors produce palatable and well-balanced, if undistinguished, wines. The suitability of a grape variety for a particular type of wine depends not only on its flavoring constituents but also on the proper balance between the components of its must. This latter factor fluctuates with the environmental conditions under which the grape is grown and with its maturity when picked. Often, in addition, there is an actual change in the basic flavor of the grape, and consequently in its suitability for certain types of wine, when it is grown under unfavorable conditions or is picked when immature, overripe, or in an otherwise unsatisfactory state.

Physical Composition at Maturity.—The stems (rachis and pedicels) on which the berries are borne in most varieties constitute from 2 to 4 per cent of the total weight at maturity. The stems are high in tannin and acid content and in addition contain resinous materials. The per-

[11] General references on this subject are listed on page 130.

centage of moisture in the stems decreases from over 75 per cent to about 65 per cent during ripening. The ratio of stem to berry weight differs with variety, season, and maturity. With a given variety, this ratio will be much lower in a dry hot season or district than in a cool season or district. Table 6 gives typical data on the changes in the weight of the stems, skins, pulp, and seeds that occur during ripening.

The fleshy pericarp, known as pulp, surrounded by skins, and in which the seeds are imbedded, composes the greater portion of the fruit itself. From 85 to 90 per cent of the crushed stemmed grapes (must)[12] is juice. The skins account for 5 to 12 per cent of the weight, and the seeds from 0 to 4 per cent. Thick-skinned or heavy-seeded varieties

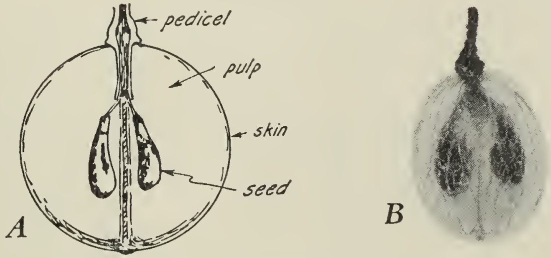

Fig. 1.—*A*, Diagrammatic sketch of berry showing principal parts; *B*, photograph of xylene-cleared berry with skin removed and vascular system and seeds exposed.

may exceed these limits. The outer layers of the fruit (skin mainly) contain the greater portion of the aroma, coloring, and flavoring constituents. The skins of red grapes are also high in tannin. The seeds, however, are highest in tannin content and in addition contain important amounts of oils and resinous material. Figure 1 shows the structure of a grape berry. The pulp near the skin is less easily separated from the skins than that near the seeds. Since the former contains more sugar and less acid, the early-pressed juice, from near the seeds, is always more acid and less sweet than the late-pressed juice from near the skins.

The juice yield from grapes varies with the variety and its stage of maturity. Table 7, which gives Bioletti's data for red and white grapes, is only indicative: the actual yield obtained will depend not only on the variety and its maturity, but also on the efficiency of the crushing, stemming, pressing, and other operations. In addition, many wineries do not use a press, so that the actual yield may be somewhat less, but the alcohol recovery by washing the pomace may be larger than if the grapes were pressed.

[12] Technically "must" refers to the mixture of crushed grapes and juice. But it is also used to denote the free-run clear juice.

Chemical Composition at Maturity.—Water constitutes 70 to 85 per cent of the weight of the must. Several carbohydrates are present, the two most important being dextrose and levulose in approximately equal amounts. During maturation the levulose-dextrose ratio increases to about unity, and 17 to 25 per cent of the weight of the must when the grapes are fully ripe consists of these two sugars. Musts from overripe grapes may have levulose-dextrose ratios above one. Small amounts of pentoses, pectins, pentosans, and inosite also are present. Much larger amounts of pectin are present in the must than in the wine. When present in large amounts, however, the clarification may be difficult or may

TABLE 7

YIELDS OF STEMS, POMACE, JUICE, AND WINE FROM A TON OF GRAPES*

	Stems (from crusher)	Pomace		Fresh juice	White wine		Red wine			
		Unfermented	Fermented		New	After racking	Free run	From press	Total	After 1st racking
	lbs.	*lbs.*	*lbs.*	*gals.*	*gals.*	*gals.*	*gals.*	*gals.*	*gals.*	*gals.*
Maximum*	64.6	513.0	392.1	183.4	...	...	143.0	43.1	179.5	...
Minimum	16.2	265.0	252.0	160.4	...	...	127.8	34.7	170.9	...
Average	27.2	391.0	345.2	168.7	151.0	145.5	136.4	38.4	174.9	169.0

*Considerably higher yields have been obtained in practice under optimum conditions.

Source of data:

Bioletti, F. T. Winery directions. California Agr. Exp. Sta. Cir. **119**:1–8. 1914.

be delayed materially so that enzyme clarification is sometimes desirable. The pectin is believed to impart smoothness to wines.

The two chief acids present are malic and tartaric. During ripening, the free malic and tartaric acids gradually decrease, while the acid tartrate increases. There is a gradual drop in the total titratable acidity throughout the later stages of ripening. In California the titratable acidity of the juice of mature grapes varies from 0.30 to 1.30 per cent; but few varieties or climatic conditions yield grapes whose musts contain over 1.00 per cent acid in this state and the average may well be as low as 0.55. The "pH"[13] ranges from 2.9 to 3.9, but averages about 3.5. These averages resemble those for Algerian conditions but differ markedly from those for the cool regions of Europe. The total acid content of German musts, for example, approximates 1.00 per cent, while the pH average is close to 3.0.

According to Brémond,[14] as the percentage of free tartaric acid pres-

[13] The "pH" is a measure of the active acidity as distinguished from total acidity and is an inverse function of the concentration of hydrogen ions furnished by the acid on dissociation. The lower the pH the greater is the effective acidity.

[14] Brémond, A. Contribution à l'etude analytique et physico-chimique de l'acidité des vins. 39 p. Imprimeries la Type-Litho et Jules Carbonel Réunies, Alger. 1937.

ent increases, the pH decreases. But there is no uniform correlation between the total titratable acidity and the pH, probably because of the varying buffer capacity of the musts. Figure 2 shows, however, that during the ripening season for a single variety there is a simultaneous and inverse change in pH and total acidity; and table 8 indicates that,

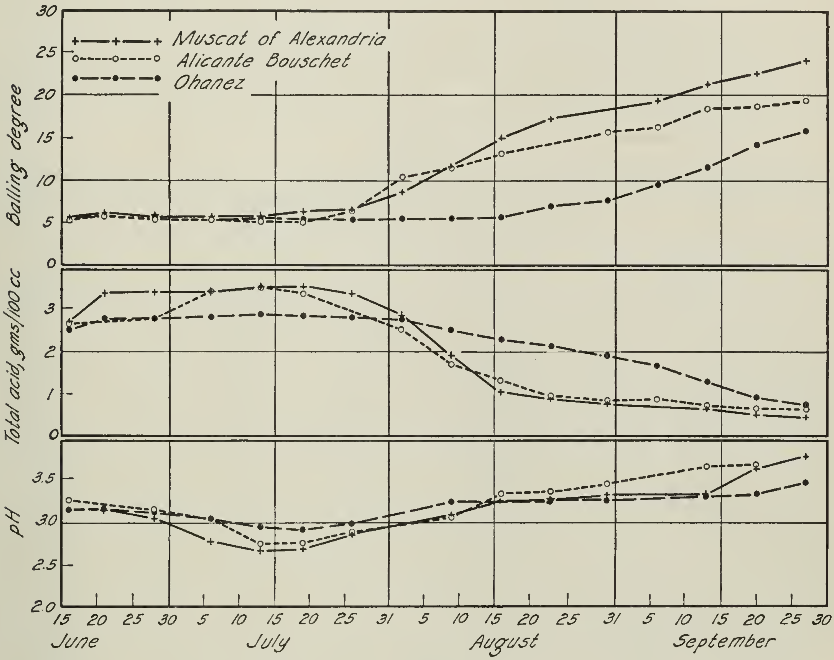

Fig. 2.—Seasonal changes in total acid, pH, and degree Balling of Alicante Bouschet, Muscat of Alexandria, and Ohanez grapes at Davis.

in general, grapes with the highest titratable acidity also have the lowest pH. The low-acid grapes also have Balling-acid ratios exceeding 45. In general, grapes with high ratios are suited to making sweet rather than dry wines. The relation of total acid, pH, and percentage of the acids present as free acid varies markedly with the variety of grape, the stage of maturity, and seasonal conditions. As Ferré[15] and others have demonstrated, although the free malic acid of green grapes may constitute 70 per cent of the total acid, in the ripe grapes it amounts to only 10 to 30 per cent. Brémond has found differences in the percentage of malic acid present in wines from the plains of Algeria as compared with those from the hills. Peynaud[16] has found marked differences in the malic acid

[15] Ferré, M. L. Indices oenologiques et rétrogradation de l'acid malique. Annales des Falsifications et des Fraudes 21(230):75–84. 1928.

[16] Peynaud, E. L'acide malique dans les moûts et les vins de Bordeaux. Revue de Viticulture 90(2323):3–12; (2324):25–30. 1939.

content at maturity in five important varieties of the Bordeaux region. The malic acid (as well as the total titratable acidity) is markedly lower in warmer years.

Nitrogenous compounds of various kinds are found in musts. Colby[17] found the total organic nitrogen expressed as protein to range from 0.01 to 0.20 per cent in musts of several varieties from different parts of California. Similar results were obtained by Niehaus[18] in South Africa. According to Muth and Malsch,[19] most of the organic nitrogen in grapes and must is present as diamino acids, peptides, and purines, with but

TABLE 8

BALLING, TOTAL ACID, AND pH OF COMMON WINE GRAPE VARIETIES FROM THE SAME REGION DURING THE 1938 SEASON

Variety	Date picked	Balling	Total acid as tartaric	pH	Balling / Total acid
		degrees	*per cent*		
Alicante Bouschet	October 18	21.9	0.60	3.57	36.5
Barbera	October 17	21.5	.95	3.20	22.6
Cabernet Sauvignon	October 17	20.7	.68	3.53	30.5
Carignane	October 3	21.0	.47	3.69	44.6
Chasselas doré	September 22	20.5	.44	..	46.6
Fresia	October 17	20.7	.75	3.55	27.6
Mission	October 10	24.0	.45	3.98	53.4
Muscat of Alexandria	October 17	20.9	.43	3.55	48.6
Nebbiolo	September 28	22.4	.81	3.16	27.6
Palomino	October 10	23.7	.37	3.79	63.0
Petite Sirah	September 21	22.3	.50	3.46	44.6
Pinot noir	September 14	22.8	.55	3.86	41.5
Sylvaner (Franken Riesling)	August 31	21.0	.69	3.54	30.4
White Riesling (Johannisberger)	October 3	22.1	.51	3.47	43.4
Zinfandel	September 21	22.8	0.55	3.58	41.5

traces of proteins. Ammonium compounds and nitrates have been found, and apparently some lecithin. The nitrogen content is undoubtedly of considerable significance in the nutrition of yeasts and also in the clarification of the wine and probably in certain types of bacterial spoilage.

The skins contain the important coloring matter of red grapes, although the Alicante Bouschet and related varieties also have red-colored pulp. Green grapes contain chlorophyll, which gradually diminishes during ripening. The red color is due to an anthocyanin that has been identified as oenin chloride and which on hydrolysis yields glucose and

[17] Colby, George E. On the quantities of nitrogenous matters contained in California musts and wines. University of California, Report of the Viticultural Work during the Seasons 1887–1893, part II, p. 422–46. 1896.

[18] Niehaus, Chas. J. G. Studies on the nitrogen content of South African musts and wines. So. African Dept. Agr. and Forestry Science Bul. 172:1–15. 1938.

[19] Muth, Fr., and L. Malsch. Versuchen zur Aufstellung einer Stickstoff Bilanz in Traubenmosten und -weinen. Zeitschrift für Untersuchung der Lebensmittel 68:487–500. 1934.

oenidin chloride. Only a limited number of varieties and species have been investigated and other compounds may also be found. Quercitrin, quercetin, and possibly also carotene and xanthophyll are present. The intensity of color in red grapes differs with the variety. In addition there is less color in grapes of the same variety grown in a warm as compared with a cold region.

Tannin occurs chiefly in the skins, stems, and seeds. In the free-run juice a very little is dissolved, but the amount is markedly increased by prolonged contact of the juice with these parts of the fruit during fermentation. The tannins vary in nature, being complex derivatives of polyhydroxy-benzoic acids; grape-seed tannin, for example, is largely a catechol tannin. Degradation products of tannins such as the resinous substances called phlobaphanes are present also.

At maturity the grapes also contain numerous other substances. The ash amounts to 0.2 to 0.6 per cent of the fresh weight. Potassium, sodium, calcium, and iron phosphates, sulfates, and chlorides account for most of the ash. Lasserre[20] found 120 to 130 parts per million of calcium and 13 to 90 of magnesium in grapes, the ratio of magnesium to calcium being always below 1 in the must but exceeding 1 in both red and white wines. Fresh must contains 1 to 30 parts per million of iron, a large percentage of which is precipitated during oxidation following fermentation. Some is also absorbed by the yeast. Much of the copper content of the must is also lost during fermentation. The copper, lead, and arsenic content of the California musts is exceedingly low, since sprays containing these substances are rarely used in this state. Small amounts of ascorbic acid (vitamin C)[21] and somewhat larger amounts of some of the B vitamins[22] have been found in the fresh grape. Oxidase, tannase, and possibly pectinase enzymes are present.[23] Grapes attacked by *Botrytis cinerea* apparently contain large amounts of oxidase as well as some glycerin. Fats have been found in the must—a discovery that is not surprising in view of the considerable quantity of oil in the seeds. In certain grapes—

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[20] Lasserre, A. Sur les quantités de silicium, de calcium et de magnésium contenus dans les vins et leurs moûts. Procès-Verbaux des Séances de la Société des Sciences Physiques et Naturelles de Bordeaux. 1932–33:66–72 1933.

[21] Venezia, M. Sull'acido ascorbico (vitamin C) nell'uva del vino. Annuario, R. Staz. Sper. de Vitic. edi. Enol. 8:67–82. 1938. *Abstracted in:* Chemical Abstracts 33:5980. 1939.

[22] Randoin, M. Étude comparative au point de vue des vitamine hydrosolubles de la valeur nutritive du raisin blanc et du raisin noir. La Journée Vinicole **13**(3643):1–2. 1939.

Morgan, Agnes Fay, Helen L. Nobles, Adina Wiens, George L. Marsh, and Albert J. Winkler. The B vitamins of California grape juices and wines. Food Research **4**: 217–29. 1939.

[23] Semichon, L., and M. Flanzy. Sur les pectines des raisins et le moelleux des vins. Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences [Paris] 183(6):394–96. 1926.

Muscats, for example—unidentified, volatile, aroma-producing substances are present in easily detectable amounts. Judging from superficial observation, the amount of such substances varies with the ripeness of the grapes and with the climatic conditions; it generally increases with maturity, in the warmer districts, up to a certain point—at least,

TABLE 9

RANGES IN COMPOSITION OF MUSTS

Constituent	Range	Comment
	per cent	
Water	70–85	
Extract	15–30	
Carbohydrates:		
Sugars	12–27	Dextrose and levulose
Pectins	0.1–1.0	Includes gums, etc.
Pentosans	0.1–0.5	Small amounts of pentoses also present
Inosite	Traces	Larger amounts in high-acid musts
Acids, total*	0.3–1.3	
Malic	0.1–0.5	
Tartaric	0.2–0.8	Potassium acid tartrate also present
Citric	Traces	
Tannin	0.0–0.2	
Nitrogen	0.01–0.20	In proteins, ammonia, etc.
Ash	0.2–0.6	
Ash constituents		
	grams per liter	
Iron	0.001–0.030	Contact of must with iron surfaces increases this
Potassium	0.400–2.000	Increased by addition of potassium salts; varies markedly with maturity and growing condition
Calcium	0.040–0.150	Contact with concrete tanks increases this
Magnesium	0.050–0.200	
Aluminum	0.001–0.040	Contact with certain filter aids increases this
Sodium	0.050–0.200	
Manganese	0.000–0.050	

*pH range 2.9-3.9.

Sources of data:

Ventre, J. Traité de vinification pratique et rationnelle. II. Le vin. 487 p. Librairie Coulet, Montpellier, France. 1931. Von der Heide, C., and F. Schmitthenner. Der Wein. 350 p. F. Vieweg und Sohn, Braunschweig, Germany. 1922.

for some varieties. Table 9 summarizes part of these data, modified for California conditions.

Measurement of Maturity.—The relative proportions of several of these constituents determine the maturity of the grape and its suitability for various types of wines. The most obvious changes during maturation are the gradual increases in the sugar content and in the pH of the fruit; at the same time, the titratable acidity, together with the free malic and tartaric acid content, rapidly decreases. In red varieties the anthocyanin color gradually deepens, and in white varieties the greenish color fades.

The proper stage for picking depends on the use for which the grapes are intended. Dessert and appetizer wines and natural sweet table wines require grapes high in sugar and low in acid. Wines of this composition are obtained from grapes grown in the warmer districts or from grapes left on the vines until late in the season. Grapes for dry table wines, however, should be picked when their sugar is barely sufficient for producing the proper alcohol content; that is, they should not remain on the vines until the total acid has become abnormally low. Drying out on the vines should therefore be avoided. Dry table wines made from overmature grapes will not be as palatable, will not ferment out, and will be of poorer quality than those made from properly matured grapes.

The measurement of maturity involves the determination of both the total acid and sugar contents. It is complicated by the fact that different varieties have widely different total acid contents when their sugar reaches the same level, a fact that affects the suitability of the several varieties for the different types of wine. Table 8 shows the differences between some of the common grapes, all grown in the same vineyard and picked as nearly as possible at the same stage. In countries where the minimum alcohol content is not important, the total acid might be a partial criterion of maturity. In California, however, where the wines must have a minimum alcohol content of 11 per cent, the total acid differs too much from variety to variety to be useful by itself, so that the sugar content also must be measured.

In California musts, a fairly uniform percentage of the soluble solids of the mature fruit is sugar. The soluble solids of the juice are usually estimated by a Balling (or Brix) hydrometer.[24] The actual chemical determination of sugar is more accurate but much less simple. The sample used, whether it be taken from fresh grapes in the vineyard during ripening or from a load of fruit being delivered at the winery, must be representative, from 5 to 10 pounds or more, according to the method of selection. The actual test is made by crushing the grapes, either in a press or with the hands, and straining the juice into a cylinder. The hydrometer is then floated in the liquid, and a reading made at the bottom of the meniscus. Accuracy depends on a valid sample, a clean cylinder, a reliable hydrometer, uniform and complete extraction of the sugar from the grapes, and freedom from extraneous matter and air bubbles in the strained juice. With overripe fruit, it is difficult to obtain sufficiently complete extraction of the sugar (particularly if partly dried berries are present). The most convenient hydrometers have an enclosed thermometer and correction scale, so

[24] Rogers, S. S., H. B. Stafford, and A. E. Mahoney. The wine grape testing law. California Dept. Agr. Bul. 29(1):3–11. 1940.

that the correction for temperature is very simple. For other hydrometers the temperature of the liquid is measured, and 0.03 degrees Balling is added for each degree Fahrenheit above that for which the hydrometer is calibrated; or 0.03 degrees Balling is subtracted for each degree below the calibrated temperature. Since the Balling reading does not actually measure sugar content, it must be corrected for

TABLE 10

INFLUENCE OF REGION ON THE COMPOSITION OF GRAPES PICKED AT APPROXIMATELY THE SAME STATE OF MATURITY

Variety	Balling			Total acid			pH		
	Fresno*	Davis†	Bonny Doon‡	Fresno	Davis	Bonny Doon	Fresno	Davis	Bonny Doon
1937									
	degrees	*degrees*	*degrees*	*per cent*	*per cent*	*per cent*	*pH*	*pH*	*pH*
Alicante Bouschet	—	18.8	18.9	—	0.78	1.20	—	3.47	3.10
Burger	—	17.8	17.6	—	.55	0.81	—	3.46	3.15
Cabernet Sauvignon	22.9	22.4	20.7	0.65	.67	1.10	3.48	3.63	3.41
Carignane	21.8	21.8	—	.62	.70	—	3.67	3.58	—
Sauvignon vert	23.3	—	20.3	0.50	—	0.67	3.81	—	3.24
Semillon	—	19.0	18.0	—	.67	0.97	—	3.45	3.10
Zinfandel	—	22.4	21.3	—	0.61	0.86	—	3.58	3.28
1938									
	degrees	*degrees*	*degrees*	*per cent*	*per cent*	*per cent*	*pH*	*pH*	*pH*
Alicante Bouschet	—	19.9	19.1	—	0.63	1.29	—	3.63	2.95
Cabernet Sauvignon	22.0	20.7	—	0.46	.68	—	3.58	3.53	—
Sauvignon vert	24.2	24.3	22.4	.44	.57	0.57	3.67	3.81	3.28
Semillon	21.0	18.1	24.1§	.41	.55	0.69	3.42	3.36	3.07
Zinfandel	21.0	22.8	24.7§	0.55	0.55	1.16	3.51	3.58	3.14

* Fresno—4,680 day-degrees of temperature above 50° Fahrenheit during the growing season.
† Davis—3,618 day-degrees of temperature above 50° Fahrenheit during the growing season.
‡ Bonny Doon—2,400 day-degrees of temperature above 50° Fahrenheit during the growing season.
§ Figures are high due to late harvesting and small crop on vines.

the effect of salts, acids, and the like. Usually 2.0 to 2.5 (the approximate nonsugar, soluble-solids content of the juice of mature grapes) is subtracted from the hydrometer reading to obtain the approximate actual sugar content.

Influence of Environment on Composition.—The chief environmental factor that influences the composition of grapes is temperature. The interior valleys of California are approximately 55 to 60 per cent hotter during the growing season than the coastal counties. In the warmer districts, grapes mature much earlier and, at the same degree of sugar, have less total acid, a higher pH, and less color.

Table 10 indicates the differences in acidity and pH of certain varieties in the Fresno, Davis, and Bonny Doon (near Santa Cruz) districts for the 1937 and 1938 seasons harvested at approximately the same Balling degree. As will be noted, not all the samples could be harvested at the same stage. During the latter stages of maturation, the total acid drops about 0.04 per cent each day, or for each degree rise in Balling the total acid decreases about 0.15 per cent. The figures indicate a significant difference in the total acid and pH of the grapes in these districts. Note that

TABLE 11

EFFECT OF SEASON AND VARIETY ON THE COMPOSITION OF MUST AND WINE

	Average date collected		Must: Balling		Wine: Alcohol		Wine: Total acid		Wine: Color intensity*	
	1935	1936	1935	1936	1935	1936	1935	1936	1935	1936
			degrees	*degrees*	*per cent†*	*per cent†*	*per cent*	*per cent*		
Alicante Bouschet	Oct. 1	Sept. 23	21.7	22.9	10.9	12.3	0.61	0.57	64	63
Burger	Sept. 30	Sept. 19	19.8	19.5	9.6	11.0	.66	.55	—	—
Carignane	Sept. 30	Sept. 19	22.3	23.3	10.9	12.4	.70	.50	27	22
Palomino	Sept. 24	Sept. 30	21.5	22.9	11.0	12.5	.38	.36	—	—
Petite Sirah	Sept. 28	Sept. 22	23.2	25.6	11.3	13.9	.67	.56	77	59
Zinfandel	Oct. 1	Sept. 19	24.7	23.9	12.8	13.5	.71	.58	31	19
Average 6 varieties	Sept. 29	Sept. 19	22.2	23.1	11.1	12.6	.62	.52	50	41
Average of 240 samples‡	Sept. 30	Sept. 21	22.1	23.0	11.0	12.2	0.61	0.50	39	33

* These figures represent the relative intensity of color expressed on an arbitrary scale, the higher the figure the greater is the concentration of pigment.

† Per cent by volume.

‡ Represents about 40 varieties from several districts of California.

Source of data:

Winkler, A. J., and M. A. Amerine. What climate does—the relation of weather to the composition of grapes and wine. The Wine Review 8 (6):9–11. 1937.

the average summation of temperature at Davis is only 77 per cent of that at Fresno, while Bonny Doon has barely 50 per cent as much heat during the ripening season at Fresno. The total acid in the grapes from Bonny Doon, however, is almost twice as much as that in Fresno grapes.

Table 11 indicates the marked differences between seasons. Not only does the picking date for the same degree of Balling come earlier in the hot season, but the acids and colors are lower. Even though the samples in 1936 were picked considerably earlier, the Ballings were slightly higher—a fact that will not, however, account for the lower average total acid content.

The influence of regions on the color of grapes is indicated in table 12. Thus in a moderately cool coastal valley, such as Napa, a variety may be suitable for making a well-colored red table wine, whereas at Fresno the same variety would not have sufficient color or acid. In addition, with its higher pH at Fresno (see table 10), it would be less satisfactory for dry-wine fermentation; and the color would be less attractive at the higher pH. As a matter of fact varieties such as the Grenache will make wines of fairly satisfactory color in the cooler districts; but in the San Joaquin Valley area they are frequently used for distilling material, or pressed for use as white musts for dessert wines.

In general, the warmer the season or the district, the higher are the sugar content and pH on a given date and the less are the total acid and color. Other factors being equal, the cool districts are the most likely to give naturally well-balanced musts for dry table wines. According to the experience of most wine makers, the best quality of such wines is produced in districts where the musts are naturally well balanced. But even in districts where the musts are deficient in acidity, wineries can produce satisfactory bulk dry table wines by using one of the varieties,

TABLE 12

INFLUENCE OF REGIONAL CONDITIONS ON COLOR OF GRAPES

Variety	Regions and averaged color value*				
	Delano, Fresno	Lodi, Guasti, Davis	Livermore Valley, Asti, Ukiah	Napa Valley, Santa Clara Valley	South Sonoma County, Santa Cruz Mts.
Alicante Bouschet	74	85	92	143	235
Carignane	45	49	57	83	100
Mataro	8	14	20	55	65
Petite Sirah	70	80	89	143	200
Zinfandel	27	44	52	62	200

* These figures represent the relative intensity of color expressed on an arbitrary scale; the higher the figure the greater is the concentration of pigment.

Source of data:

Winkler, A. J., and M. A. Amerine. Color in California wines. II. Factors influencing color. Food Research 3 (4):439–47. 1939.

such as Barbera, which retain their high acid when grown in a warm climate; by picking high-acid, second-crop grapes at the same time as the low-acid, first-crop; by picking earlier; by picking a high-acid, low-sugar variety at the same time as the low-acid, high-sugar variety and combining the musts; or by adding acid to the must. Such practices are, however, not suited to the production of quality wines.

RECOMMENDED GRAPE VARIETIES

The adaptation of specific varieties to the different climatic regions of California has been an important study of the California Agricultural Experiment Station. Information regarding origin, cultural characteristics, and type of the important wine-grape varieties will be found in

Extension Circular 116.[25] The following data cover more specifically the recommendations that can be given for types of wines deriving their flavor and color from a single variety. When the standards for other wine types are more definite and when better information on the adaptation of varieties to regions is available, more specific directions for the grapes to be used in these types can be given.

Varieties of Grapes for Varietal Types of Wines.—Table 13 summarizes the information concerning the grapes for the types of wines having a characteristic flavor derived from a single variety of grapes. A number of grapes with a distinctive and attractive varietal flavor are not now used, however, to any extent in producing such wines in California. Fresia, Nebbiolo, and Sangioveto in all districts, and Tannat and Valdepeñas in at least the cooler districts, appear suitable for producing distinctive wines without correction of their musts.

Chardonnay, Pinot blanc, Pinot noir, Gamay, Peverella, and Grignolino make distinctively flavored wines but must be harvested early for table-wine making. Blending of these varieties reduces their distinctiveness, but is sometimes necessary in order to produce a wine having the desirable alcohol-to-acid ratio.

Petite Sirah is grown on a large acreage in California. When properly aged, it makes wine of characteristic flavor which is frequently too heavy and alcoholic for a straight varietal wine; when diluted too much by blending, it does not maintain its characteristic flavor. It does not equal in quality such varieties as Pinot noir, Gamay, or Cabernet Sauvignon, but, obviously, will be used because of its availability, and its high color content and body.

Varieties for Wines without a Characteristic Varietal Flavor.—Specific recommendation for nonvarietal types of wine cannot be made because of the poorly established standards for the types. Varieties that produce satisfactory table wines in the cooler districts frequently cannot do so in the hot districts, and vice versa. Most of these varieties continue to be used for wine making simply because of their cheapness, productiveness, and availability. New plantings intended for fine wines should be made only in suitable locations with the best varieties, the most important of which are listed in table 13. Plantings for ordinary bulk wines, however, should utilize the more highly productive varieties.

In addition to ones previously mentioned, the following red varieties can be recommended for red table wines in the cool districts: Carignane, Mondeuse, and Refosco. These, properly made and aged, should produce satisfactory ordinary and occasionally fine wines of the California claret

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[25] Jacob, H. E. Grape growing in California. California Agr. Ext. Cir. 116:1–79. 1940.

TABLE 13

VARIETIES OF GRAPES FOR VARIETAL TYPES OF WINES

Variety	Type of wine	Character of wine	Regional adaptation	Blending and aging requirements
Aleatico	Aleatico	Natural sweet	Moderately warm districts	None and short-aging
Barbera	Barbera	High acid, dry red	All except coolest districts	Blend if too high in acid
Cabernet Sauvignon	Cabernet	Dry red; high quality	Cool districts	None, if possible; 3-4 years in wood
Chardonnay	Chardonnay	Dry white	Coolest districts	None; prevent oxidation
Chasselas doré	Golden Chasselas or Gutedel	Dry white; medium quality	Coolest districts	Raise acidity; matures early
Gamay	Gamay	Fruity, dry red	Cool districts	None; matures early
Grignolino	Grignolino	Dry pink	Moderately cool districts	None
Pinot blanc	Pinot blanc	Dry white	Cool districts	None; medium aging
Pinot noir	Pinot noir	Dry red	Coolest districts	None; prevent oxidation
Riesling*	Riesling	Dry white	Coolest districts	Raise acidity; matures early
Sauvignon blanc	Sauvignon blanc	Dry white	Moderately warm districts	Should not be diluted
Semillon	Semillon	Natural sweet	Moderately warm districts	None or with Sauvignon vert
Traminer	Traminer	Dry white	Coolest districts	Raise acidity
Zinfandel	Zinfandel	Dry red; ordinary quality	Cool districts	Should not be diluted; matures early

*White Riesling (Johannisberger), Sylvaner (Franken Riesling), Wälschriesling, Kleinberger Riesling, and Gray Riesling (in approximately the decreasing order of their distinctive character and utility for making high-quality dry, white table wines).

and California Burgundy types. Other varieties that are sometimes satisfactory are the Beclan, Charbono, Grenache, Mataro, Petite Verdot, and Saint Macaire. Rarely, if ever, advisable for these types of wines are the Mission, Aramon, Alicante Bouschet, Chauché noir, and Blue Portuguese; although the Aramon may occasionally be useful for pink-wine production.

For ordinary dry white table wines, few varieties are as satisfactory as those with a varietal flavor previously mentioned. Folle blanche, Burger, Sauvignon vert, and Saint Emilion (Ugni blanc) are useful for blends for neutral wines, although none of these regularly can produce a high-quality dry white table wine by itself. The Palomino and Green Hungarian are even less desirable, by themselves or in blends.

The natural sweet wines—California dry sauterne, California sweet sauterne, and the Chateau type—require high sugar, medium body, moderately low acid, and a good flavor, all of which are obtainable from the Semillon, grown in moderately warm districts. Although its flavor is too pronounced, the Sauvignon vert makes a satisfactory wine for blending; but it should not be the major constituent of the blend. Rarely advisable for natural sweet white wines are the Palomino, Burger, Folle blanche, Saint Emilion, and Green Hungarian.

The deficiencies of many of the varieties mentioned, as far as their adaptability for producing ordinary-quality table wines is concerned, can be corrected by judicious blending, preferably of the grapes at the time of crushing, in which case the composition of the blend for each type of wine should be kept as uniform as possible from year to year.

ALCOHOLIC FERMENTATION[26]

NATURE OF FERMENTATION

The transformation of carbohydrates, usually sugars, into products characteristic of the particular microörganism and of the effective environmental conditions is generally called "fermentation." This transformation is brought about through the activity of enzymes elaborated by the living microorganism. In the alcoholic fermentation, the chief products are alcohol and carbon dioxide gas. Although alcoholic fermentations may be accomplished by various microörganisms—yeasts, molds, or bacteria—the yeasts possess the power of fermenting sugars with the production of largest amounts of alcohol. Yeasts vary widely in their ability to ferment sugars, in the completeness of this fermentation, and in the character of the by-products produced. In the fermentation of grape musts, the only species of yeasts used are those which can ferment the juice free of sugar and which produce desirable by-products.

[26] General references on this subject are listed on page 131.

Products.—The quantity of alcohol and carbon dioxide formed and the kind and concentration of by-products varies with the strain of yeast and with the composition, temperature, and extent of aeration of the medium. It is customary to summarize the important changes occurring during alcoholic fermentation as follows:

$$\underset{\text{dextrose or levulose}}{C_6H_{12}O_6} = \underset{\text{ethyl alcohol}}{2C_2H_5OH} + \underset{\text{carbon dioxide gas}}{2CO_2}$$

TABLE 14

PRODUCTS OF ALCOHOLIC FERMENTATION, THEORETICAL AND ACTUAL, AND WITH THREE YEAST TYPES

Product	Percentage of fermentable sugar transformed					
	Theoretical	In industrial fermentations	Pasteur data	With champagne wine yeast	With Rkatsateli wine yeast	With Steinberg wine yeast
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Alcohol	51.1	48.4	48.6	47.8	48.1	48.0
Carbon dioxide	48.9	46.5	47.0	47.0	47.6	47.6
Acetaldehyde	0.0	0.00–0.08	—	0.01	0.04	0.02
Acetic acid	0.0	0.05–0.25	—	0.61	0.50	0.65
2, 3-Butylene glycol	0.0	—	—	0.06	0.09	0.10
Glycerin	0.0	2.5–3.6	3.1	2.99	2.61	2.75
Lactic acid	0.0	0.0–0.2	—	0.40	0.28	0.40
Succinic acid	0.0	0.5–0.7	0.6	0.020–0.045	—	0.015–0.053
Furfural	0.0	trace	—	—	—	—
Fusel oil (higher alcohols)	0.0	0.05–0.35	—	—	—	—

Sources of data:

For industrial fermentations: Rahn, Otto. Physiology of bacteria. p. 42. P. Blakiston's Son and Co., Inc. 1932.

For type of wine yeast: Gvaladze, V. Relation between the products of alcoholic fermentation. [Translated title.] p. 1-76. Lenin Agr. Acad. of U.S.S.R. 1936.

The process, however, is less simple than is indicated by this equation (called the Gay-Lussac equation). Alcoholic fermentation occurs in a series of well-defined stages, involving the formation of several important intermediates and the interaction of several enzyme systems.[27] Acetaldehyde, glycerin, 2, 3-butylene glycol, lactic acid, and acetic acid are constant products of alcoholic fermentation. Succinic acid is formed in appreciable quantities only in the presence of air; and other by-products such as esters and higher alcohols accumulate as a result of the action of yeast on substances other than sugar. The quantity of some of these products, calculated on the basis of percentage of fermentable sugar transformed, is shown in table 14.

According to the equation given above, theoretically the weight of

[27] Enzymes are organic substances secreted by living cells which promote or accelerate those chemical reactions upon which the life of the cell depends.

alcohol produced should be 51.1 per cent of the weight of the sugar consumed. In practice the yield of alcohol by weight is generally 47 per cent,[28, 29] the remainder of the sugar being converted into other products and used by the yeast for growth and respiration. Judging from analyses made by G. E. Colby of California wines in the pre-Prohibition era, the alcohol content by volume in wine is approximately equal to 57.5 per cent of the Balling degree of the must. This value is somewhat too high, however, at least under those commercial conditions when the free-run juice is a truly representative sample of the juice. The free-run juice does not indicate the yield of alcohol obtainable when large quantities of raisins are present. Even higher alcohol yields are obtained in such cases, frequently reaching as high as 65 per cent of the Balling reading.

French enological writers commonly assume that 1 per cent of alcohol by volume is obtained per 17 grams of sugar fermented per liter of wine. Theoretically a solution containing 170 grams of sugar per liter may yield 9.5 per cent of alcohol by weight or 11.8 per cent by volume. This would make the French usage actually a 43 per cent conversion by weight instead of 47 per cent as in this state, but if changes in weight and volume during fermentation are disregarded, the conversion is about the same as here.

EFFECT OF ENVIRONMENTAL CONDITIONS

The concentration of alcohol produced from grape juice by a given strain of yeast is influenced largely by temperature, extent of aeration, sugar concentration, acidity, and activity of the yeast. The enzymes secreted by the yeast require no oxygen for their activity. Higher amounts of alcohol are formed in the absence of air. In fermentations conducted in the presence of air, the efficiency of alcohol production is reduced, not only because oxygen interferes with the alcoholic fermentation by the enzymes, but also because of increased active respiration of sugar by yeast. The greater loss of alcohol by evaporation or entrainment in open fermentations is also a factor.

Temperature.—Temperature is extremely important; the lower the temperature, the higher the yields of alcohol in fermentation, not only because of more complete fermentation but also because of reduction in loss of alcohol by evaporation and entrainment by escaping carbon dioxide gas. Thus Müller-Thurgau,[30] having fermented samples of the

[28] Niehaus, Charles J. G. Sugar-alcohol ratios in South African musts and wines. South African Dept. Agr. Science Bul. 161:1–11. 1937.

[29] Trauth, F., and K. Bässler. Ein Beitrag zur Frage der Beziehung zwischen Mostgewicht und Alkoholgehalt und deren Nutzanwendung bei der Verbesserung der Moste. Zeitschrift für Untersuchung der Lebensmittel 72:476–98. 1936.

[30] Data cited by: Sannino, F. Antonio. Tratado de enologia. Translated from 2d Italian ed. by Arnesti Mestre. p. 137–38. Gustavo Gili, Barcelona, Spain. 1925.

same must at four different temperatures, obtained the following yields of alcohol:

Fermentation temperature, in degrees Fahrenheit	Alcohol content, in per cent by volume
48.2	17.29
64.4	15.09
80.6	12.23
96.8	8.96

The optimum temperature of fermentation for most varieties of yeast is about 85° Fahrenheit although for cold-tolerant wine yeasts it is considerably lower. At temperatures below 70°, the rate of fermentation is slow; growth and activity of wine yeast practically cease at 50°. Above 85° its vigor decreases with increase in temperature, and fermentation usually ceases at 97° to 100°. If the temperature rises to 100° during fermentation, especially in musts of high sugar content, alcoholic fermentation generally ceases—the wine "sticks." This stuck wine is liable to attack by disease-producing bacteria and will usually not referment unless special measures are taken, even though the temperature is reduced to normal.

The alcohol tolerance of yeast decreases with increase in temperature. The amount of alcohol tolerated by the enzyme systems is also less at higher temperatures. Thus Müller-Thurgau found that fermentation stopped with one yeast at about 97° Fahrenheit with 3.8 per cent alcohol by weight; at about 81° with 7.5 per cent; at about 64° with 8.8 per cent; and at about 48° with 9.5 per cent. The higher alcohols (for example, propyl or amyl) exert a greater inhibitive action. Some of those produced by wild yeasts may be involved in the sticking of wine.

Nutrition.—The rate of alcoholic fermentation also depends on the amount of yeast present, and since the numbers of yeast initially present in the must are low, conditions must be made favorable to their growth and activity, which depend on sufficient food, moisture, air supply, and temperature.

The natural acids of grapes in must have little inhibiting effect on wine yeast. In fact, by discouraging the growth of competing organisms more sensitive to acidity, they exert an indirect favorable action. To stimulate a sound fermentation, fruit acids such as tartaric, citric, and malic are sometimes added to a must low in acidity. But acetic acid, largely a product of bacterial fermentation has a strong retarding influence, apparent at 0.2 per cent and increasing with larger amounts until at 0.5 to 1.0 per cent, all yeast activity stops. The toxicity of acetic acid towards yeast becomes greater with increase in temperature.[31]

[31] Porchet, Berthe. Influence de l'acide acetique sur la fermentation du sucre par les levures, en presence d'alcool. Mitteilungen aus dem Gebiete der Lebensmittel Untersuchung und Hygiene 26:19–28. 1935.

Yeasts require oxygen for their maximum development, although most of them can live and multiply for a limited time in its absence. In the absence of oxygen, they exert their greatest power of alcoholic fermentation. In wine making, therefore, the desirable procedure is first to promote the multiplication and vigor of the yeast by growing it with abundant oxygen and then to conduct the alcoholic fermentation with only a limited supply. These conditions are brought about automatically in the usual methods of wine making. The crushing and stemming of the grapes thoroughly aerate the must. The yeast multiplies vigorously in this aerated nutrient solution until it has consumed most of the dissolved oxygen. Then alcoholic fermentation ensues. If the yeast is weakened before the wine is dry, it may usually be invigorated by aeration in some such manner as pumping over. This aeration mixes the yeast thoroughly with the fermenting liquid; removes carbon dioxide, which has a retarding influence on fermentation; and furnishes the oxygen that favors multiplication of the yeast. *Excessive* aeration during fermentation, however, results in a flat, oxidized wine of poor color and flavor.

Sugar above a certain concentration will retard fermentation; and if its concentration is high enough, the activity of the yeast may be entirely inhibited. The optimum sugar concentration for maximum alcohol production is about 28 per cent. If the initial sugar concentration is very high (30° Balling or over), sufficient alcohol and other by-products may be formed to arrest fermentation before the sugar is entirely consumed. Although 16 per cent of alcohol by volume is the maximum produced by wine yeast in ordinary wine making, under certain conditions as much as 21 per cent of alcohol can be obtained. The rate of fermentation decreases markedly with increase in alcohol content; and under practical conditions fermentations often stick at 13 to 15 per cent by volume, especially when selected yeast is not used. It is usually desirable to adjust the must to not over 24° Balling before fermentation in making dry table wines, so that the wine when dry will contain not more than 13 per cent of alcohol by volume.

By-products.—Products of alcoholic fermentation other than alcohol and carbon dioxide contribute to the flavors and aroma acquired by the wine during fermentation. Their formation depends on the strain of yeast present, the nature of the must, the temperature, the aeration, and other conditions. The acidity and tannin content of the must influence the course of fermentation as reflected in differences in amounts and kinds of by-products accumulated. At lower acidities, more acetaldehyde, glycerin, and volatile and fixed acids, but less of the aromatic principles, are formed. The extent of aeration influences the formation of fixed acids, such as succinic, and volatile acids and aldehydes, which increase in amount with increase in aeration. The effect of sugars and other constituents of the grapes on the production of aromatic principles during fermentation is poorly understood.

Temperature is among the most important factors in flavor formation. According to most enologists, more bouquet is formed in a wine by a long, slow fermentation at low temperatures than by a short, rapid fermentation at higher temperatures. In cool fermentations, the yeast apparently produces more esters and other aromatic bodies. This statement is also true for other fermented fruit products—for example, cider.

Sulfur dioxide appreciably increases the production of aldehydes and glycerin. The accumulation of aldehydes is undesirable in table wines because of their adverse effect on flavor, color, and stability. Excessive amounts of volatile acids are undesirable also.

Contribution of Microörganisms Other than Selected Wine Yeasts.—Under natural conditions no single variety of yeast, but rather a mixture of several varieties differing in alcoholic, ester, and extract-forming powers, together with certain types of acid-tolerant bacteria, will enter into fermentation. When these are present in proper proportions, under suitable conditions, a mixed fermentation ensues that is responsible for occasional excellent wine obtained by natural fermentation. Because of lack of knowledge about the relation of the associative and competitive activities of mixed cultures on quality of wine fermentations, because of the difficulty of obtaining the required flora, and because of the danger of spoilage in natural fermentations, only selected varieties of wine yeast have been used in the industry. These yeasts have been selected largely on the basis of alcohol formation rather than flavor formation, and are usually imported from select enological regions abroad. It is now known, however, that flavor formation by yeasts varies in general inversely with their alcohol-forming powers and that ester formation in wines may occur through the direct agency of yeasts and bacteria. The application of this knowledge to California conditions is yet in its infancy; and because of the danger of spoiling wines, mixed cultures are not recommended.

Not all bacteria in wines and musts are harmful; some produce desirable changes. For example, lactic-acid bacteria capable of converting malic acid into lactic, with a resultant decrease in total acidity, are especially cultivated in German and French wines of unusually high acid content.

PROPAGATION OF FERMENTATION[32]

CONTROL OF UNDESIRABLE ORGANISMS

Successful wine making depends on the skillful control of the various agents of fermentation. The appearance, flavor, and aroma of the wine, its soundness and freedom from disorder or diseases, and its resistance to bacterial attack during storage will depend upon the kind of microbial growth that occurs in the fermenting mass and upon the character of the fermentation. The growth and activity of the desired organisms—wine yeasts—must be furthered, whereas that of the undesirable organisms—wild yeast and bacteria—must be hindered. Fortunately microorganisms differ in their nutritional requirements, their requirement for oxygen, and their tolerance for acid and alcohol, in their resistance to antiseptic agents such as sulfur dioxide; and in their response to temperature.

The most serious spoilage is caused in musts by the unchecked activity of acetic and lactic acid bacteria and in wines by the activity of lactic acid bacteria. The susceptibility of wine to bacterial attack varies with acidity, alcoholic content, presence of substances liberated by decomposing yeast cells, and degree of exhaustion of nutrients such as potassium salts, phosphates, and nitrogenous matters. Wines from musts of moderate to high acid content, fermented rapidly and continuously at low temperatures, are most resistant to bacterial attack and are, besides, of better quality. For propagating the desired alcoholic fermentation, the numbers of true wine yeasts should predominate over those of other microörganisms; and the environmental conditions (composition of must, temperature, aeration) should be made favorable to their growth and activity.

BALANCING THE MUST

For best results, the sugar, acid, and tannin content of the grape juice should be properly balanced. This balance is best obtained by selecting suitable varieties and by harvesting at the proper stage. Unfortunately such practices are not always followed, especially in California, where the grapes are harvested with too much sugar for dry table wines rather than too little as in Europe, and where it is often necessary to ameliorate the must.

Acid.—The acid content of the must greatly affects the course of fermentation and also the preservation of the wine. At the optimum acidity, flavor formation occurs to a higher degree, the growth of undesirable organisms is checked more completely, and the wine obtained is more resistant to bacterial attack. What this optimum acidity is for Califor-

[32] General references on this subject are listed on page 132.

nia conditions is difficult to say. In France an acidity (expressed as tartaric acid) of 0.6 grams per 100 cubic centimeters of must is considered satisfactory for natural sweet table wines, and 0.7 to 0.9 for most of the white and red table wines. The acidity required increases with temperature. Under Portuguese conditions the acidity of the must is adjusted in accordance with the data in table 15. Similar if less drastic

TABLE 15
Correction of Acidity in Bairrada, Portugal

Type of must	Fermentation temperature	Initial acidity as tartaric acid	Tartaric acid to be added	
	degrees Fahrenheit	*grams per 100 cc*	*grams per hectoliter*	*pounds per 1000 gallons*
White	Below 78.8	1.0	0	0.0
		0.9	5	0.4
		0.8	10	0.8
		0.7	15	1.3
		0.6	25	2.1
		0.5	40	3.3
		0.4	50	4.2
White	78.8 – 86.0	1.0	0	0.0
		0.9	8	0.7
		0.8	15	1.3
		0.7	22	1.8
		0.6	35	2.9
		0.5	60	5.0
		0.4	75	6.3
White Red	Above 86.0 78.8–86.0	1.0	0	0.0
		0.9	10	0.8
		0.8	20	1.7
		0.7	30	2.5
		0.6	50	4.2
		0.5	80	6.7
		0.4	100	8.3
		0.3	120	10.0

Source of data:
Pato, Mario dos Santos. Química-física aplicada aos mostos e aos vinhos. Estação Viti-Vinícola da Beira Litoral (Bairrada) Bol. **1**:57. 1932.

corrections would improve the properties of ordinary California dry table wines. The acid deficit in the must is made up, preferably, by the addition of tartaric acid, since an appreciable amount of the added tartaric acid is later removed from wine as cream of tartar, which lowers the titratable acidity and diminishes the sourness of the wine without greatly changing the pH. Because of this loss of acid, a greater amount of tartaric acid is required, however, than of acids such as citric. According to Fornachon,[33] the addition of tartaric acid to the must insures that the primary fermentation will take place under conditions favorable

[33] Fornachon, J. C. M. Bacterial fermentations in fortified wines. 19 p. Australian Wine Board Publication on Wine Investigations. 1938. (Mimeo.)

for the healthy growth of yeast cells, and that fermentation will proceed more steadily in the acidified must, so that control of temperature is facilitated. Acidification also aids in preventing the clouding caused by metallic impurities such as iron and copper salts.

Tannin.—The addition of tannin is not necessary in the fermentation of red wine, since the skins and seeds of grapes form a ready source of tannin. In certain Old World regions, particularly Algeria, tannin is added to free-run white grape must; and this practice is also common in Australia. The amount usually added is ⅔ to 1 ounce per 100 gallons. Although Turbovsky and his co-workers[34] did not find that the addition of tannin prevented the development of undesirable organisms, it apparently does affect the by-products of alcoholic fermentation. In California, tannin deficiencies in white wines are customarily made up by the less satisfactory procedure of adding tannin to the wine rather than to the must.

Other Substances.—Deficiencies in other constituents necessary to successful alcoholic fermentation are rare in California grapes. There are usually sufficient potassium, phosphate, and assimilable nitrogenous material to support the growth and activity of yeast. The addition of yeast foods such as urea and ammonium phosphate is rarely necessary and sometimes harmful, the phosphates particularly contributing to white casse (see p. 126).

STUCK WINES

To obtain sound wines, a progressive continuous fermentation is necessary. Cessation of fermentation while there still remains some fermentable sugar is undesirable. A stuck wine is one in which the alcoholic fermentation has ceased while there still remains too much unfermented but fermentable sugar. Red wines stick more often than white. Sticking is caused by too high a temperature in the fermenting vat, by the presence of too much sugar, or by infection of the must with acetic acid bacteria.

Stuck wines are often spoiled rapidly in storage by development of lactic acid bacteria unless sulfur dioxide or metabisulfite has been used. The high temperatures that often occur in sticking especially favor the development of these and other wine-disease bacteria.

Procedure.—The most generally applicable and widely used method for handling stuck wines, red or white, is to run the wine into the storage vat and add a large starter of actively fermenting must. Another successful method consists in adding small amounts of the stuck wines to freshly crushed grapes or to vats in active fermentation. If the sticking

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[34] Turbovsky, M. W., F. Filipello, W. V. Cruess, and P. Esau. Observations on the use of tannin in wine making. Fruit Products Journal 14:106–7. 1934.

is caused by too high sugar content, then water must be added to dilute the wine so that after fermentation the alcohol content will not exceed 13 per cent by volume. Also 20 to 50 per cent by volume of actively fer-

TABLE 16

Effect of Temperature of Incubation* and Strain of Acetobacter on Acetification of Must

Yeast 66 with *Acetobacter* number	Volatile acid as acetic			
	At 77° Fahrenheit	At 87.8° Fahrenheit	At 98.6° Fahrenheit	At 107.6° Fahrenheit
	grams per 100 cc	*grams per 100 cc*	*grams per 100 cc*	*grams per 100 cc*
68	0.360	0.465	0.741	0.239
69	0.288	0.429	0.771	0.192
73	0.279	0.252	0.571	0.114
83	0.562	0.321	0.546	0.184
84	0.233	0.498	0.551	0.110
85	0.258	0.465	0.609	0.140
86	0.145	0.270	0.402	0.158
88	0.203	0.543	1.164	0.176
90	0.204	0.498	0.648	0.098
92	0.180	0.186	0.300	0.260
98	0.189	0.477	0.903	0.286
99	0.165	0.228	0.468	0.256
100	0.621	0.588	0.780	0.238
101	0.276	0.183	0.633	0.246
102	0.147	0.213	0.537	0.180
108	0.180	0.282	0.405	0.036
109	0.102	0.306	0.477	0.268
110	0.136	0.117	0.171	0.175
111	0.099	0.303	0.591	0.162
112	0.153	0.330	0.618	0.138
113	0.153	0.149	0.606	0.535
114	0.183	0.333	0.483	0.480
115	0.150	0.172	0.378	0.220
116	0.297	0.177	0.516	0.225
117	0.165	0.306	0.510	0.326
118	0.168	0.168	0.450	0.381
119	0.105	0.180	0.324	0.305
A.T.C.C.† 4920 alone‡	.....	0.180	0.068	.....
Yeast 66 alone	0.050	0.054	0.069	0.021
Blank	0.012	0.012	0.012	0.012

* Incubation period of 3 days.

† American Type Culture Collection No.

‡ Volatile acid not produced by other typical *Acetobacter* strains in absence of yeast.

Source of data:

Vaughn, Reese. Some effects of association and competition on *Acetobacter*. Journal of Bacteriology **36**:357-67. 1938.

menting must or pomace should be mixed with the stuck wine if the fermentation has become very slow. If sticking results from lowering of the temperature, the wine should be warmed to 80°–85° Fahrenheit. Moderate aeration to invigorate the yeast is also recommended in all attempts to referment stuck wines. Occasionally the addition of small amounts of ammonium phosphate, urea, or potassium phosphate is useful.

Acetified Musts.—When musts containing many acetic-acid bacteria and few yeasts are fermented under conditions unfavorable to the rapid multiplication of yeasts, there occurs a rapid acetification that retards alcoholic fermentation. Vaughn found the bacteria responsible for this to be *Acetobacter* but not the usual strains (see table 16). All strains of *Acetobacter* examined by him formed "mousy" off-flavor in grape juice. The rate of acetification was influenced by the types of yeasts grown in association with the bacteria, by the strains of the bacteria, and by the temperature. The effect of temperature, which is particularly striking, is shown in table 16. The use of sulfur dioxide to check the growth of acetic-acid bacteria, together with cool fermentation and pure yeast, will prevent this condition. Any must spoiled by acetification should be discarded, for it cannot be converted into a salable grape product. If blended with sound wines, it will merely spoil them, and its presence in the winery is a dangerous source of potential contamination.

STABILIZATION OF WINE BY REMOVAL OF NUTRIENTS

Nutrient elements are absorbed by the yeast during fermentation; and if this absorption is so managed that it causes a depletion of some necessary element, the wine will be immune to bacterial attack. Although the conditions favoring the most active and complete removal of nutrients by yeast are not known, Boulard[35] and Vandecaveye[36] have shown that successive generations of yeast can deplete the nutrients sufficiently to prevent refermentation. This practice is followed in part in the making of champagne, sauterne, and—notably—spumante wines. Low temperature, high acidity, aeration, and prompt removal of yeast cells favor the process. It is a procedure worthy of consideration in California.

USE OF SULFUR DIOXIDE

Sulfur dioxide (SO_2), a gas at ordinary temperatures and pressures, is widely used in preparing and preserving wine. It is usually added as a gas under pressure, as a solution of sulfurous acid, or as a metabisulfite, most often potassium metabisulfite. In solution it forms sulfurous acid which is responsible for its properties. Its utility is based upon its selective antiseptic effect and upon its reducing or antioxidative properties. It also exerts a clarifying, dissolving, and acidifying influence.

The use of excessive amounts of sulfur dioxide should be avoided because it not only detracts from the flavor of the wine and interferes

[35] Boulard, M. Sur un procédé permettant d'arrêter à volonté les fermentations à n'importe quel moment. Comptes Rendus des Séances de l'Académie d'Agriculture de France 12:615–20. 1926.

[36] Vandecaveye, S. C. The effect of successive generations of yeast on the alcoholic fermentation of cider. Journal of Agricultural Research 37:43–54. 1928.

with the natural aging but also leads to the production of undesirable turbidities and deposits when copper salts are present in wine. None or only the minimum quantity necessary for proper control and fermentation should be used. *When proper sanitary precautions are used in picking, crushing, fermenting, and storage, it need not be used in objectionable amounts.* Small doses repeated as necessary are preferable to a single large dose.

Antiseptic Power.—The antiseptic power of sulfur dioxide depends upon the composition of the must, the kind of microörganism, the activity of the organism, and the temperature. Sulfur dioxide added to must will rapidly combine with certain substances, particularly sugars and aldehydes. In the combined form, it is markedly less antiseptic, only about one-sixtieth as much as in the free. The proportion of combined sulfur dioxide increases with the sugar content; it decreases with increase in the amount of sulfur dioxide added and with increases in temperature and acidity of the must.

Wine yeasts are less sensitive to sulfur dioxide than are most of the common yeasts, molds, and bacteria occurring in grapes or wine. Very small amounts of sulfur dioxide (equivalent to 5 ounces of potassium metabisulfite per ton of grapes in most cases) suffice to prevent growth of molds and wild yeasts. As Cruess[37] and others have shown, 100 parts per million of sulfur dioxide (6 ounces of potassium metabisulfite per ton) will eliminate over 99.9 per cent of the active cells of microörganisms from normal musts. By properly timing the sulfiting and the addition of wine-yeast starter, the full effect of the maximum amount of free sulfur dioxide is exerted on the injurious organisms, while the wine yeast is exposed only to the minimum amount of free sulfur dioxide. Furthermore, the wine yeasts can adapt themselves to sulfur dioxide and become comparatively resistant to it.

The antiseptic action of sulfur dioxide towards microörganisms, particularly yeasts, varies with the stage of development and the numbers, being greater towards the resting or sporulating yeasts and more effective the lower the numbers present. Yeast in full activity is more resistant to sulfur dioxide, partly because of the rapid fixation of the latter by the aldehydes formed in fermentation, partly because of the mechanical entrainment of sulfur dioxide gas by carbon dioxide gas, and partly because of the natural increase in resistance of the cell.

The lower the temperature of fermentation, the lower the concentration of sulfur dioxide required to prevent the development of undesirable microörganisms.

[37]Cruess, W. V. The effect of sulfurous acid on fermentation organisms. Journal of Industrial and Engineering Chemistry 4:581–85. 1912.

The amount of sulfur dioxide to be added to a given must to control the fermentation depends on the degree of ripeness and soundness of the grapes, the temperature of the grapes and must, and the weather conditions at the time of crushing. Overripe grapes rich in sugar and low in acid, moldy grapes, and warm grapes require more sulfur dioxide than cool, sound grapes of moderate sugar and acid content. In Europe the amount usually added in hot regions is 120 to 150 parts per million; in cool regions, 20 to 40 parts. How much sulfur dioxide should be added under various conditions of ordinary commercial operation in California is indicated in table 17.

TABLE 17

Amount of Sulfur Dioxide to Be Added under Various Conditions

Condition and temperature of grapes	Liquid sulfur dioxide		6 per cent sulfurous acid solution		Potassium metabisulfite	
	Per 1,000 gals. of must	Per ton of grapes	Per 1,000 gals. of must	Per ton of grapes	Per 1,000 gals. of must	Per ton of grapes
	oz.	*oz.*	*gals.*	*pints*	*oz.*	*oz.*
Clean, sound, cool, and underripe	10	2	1¼	2	20	3½
Sound, cool, optimum maturity	15	2½	2	3	31	5
Moldy, bruised, hot, overripe, low in acid	36	6	3¼	4¼	56	9

Clarification.—In sufficiently high amounts, sulfur dioxide acts as an acid in causing a rapid and complete clarification of must, through neutralization of the negative charge on the colloids present in suspension. Its use for this purpose is limited, however, to the clearing of white must before fermentation. The clearing in this case is largely mechanical, the sulfur dioxide merely inhibiting the fermentation long enough for the skins, seeds, particles of pulp, and other debris to settle out. About 60 parts per million of sulfur dioxide—approximately ½ of a pound of sulfur dioxide to 1,000 gallons—are used.

Dissolving Action.—When sulfur dioxide is added to water, it forms sulfurous acid. This acid may be considered as fairly strong, able to cause the solution of certain substances. Thus sulfiting increases the fixed acidity, the extract, and the alkalinity of the ash because of its solvent effect on cream of tartar. It also results in higher color in red wine by its solvent action on the coloring matters in the skin, although if excessive amounts are used its bleaching action will mask this solvent action.

Acidifying Action.—A constant increase in total acidity of wines obtained from sulfited musts is among the most characteristic effects of the use of sulfur dioxide in vinification. This acidification results from the dissolving and antiseptic powers of sulfur dioxide, by which cream of tartar is converted into soluble potassium acid sulfite and tartaric acid while the development of fixed-acid-destroying microorganisms is prevented. In addition, part of the sulfurous acid present is converted by oxidation to sulfuric acid. The acidifying action of the sulfur dioxide itself is small, however, being only 0.082 per cent of acid

TABLE 18

EFFECT OF SULFUR DIOXIDE IN PREVENTING HIGH VOLATILE ACIDITY IN WINES

Year	Method of fermentation			Number of samples	Percentage of samples containing viable lactic acid bacteria	Composition of wine			
	Metabisulfite added	Cooling	Pure yeast			Alcohol	Volatile acid	Total acid	Sugar
					per cent	*per cent*	*per cent*	*per cent*	*per cent*
1913....	No	No	No	101	100	11.5	0.118	0.66	0.49
	Yes	No	No	6	0	12.6	0.048	0.50	0.42
	Yes	No	Yes	67	0	12.1	0.066	0.57	0.21
1914....	No	No	No	68	80	12.1	0.088	0.61	0.20
	Yes	No	Yes	56	0	12.1	0.052	0.62	0.24
1934....	No	No	No	81	81	12.7	0.173	0.80	0.52
	Yes	No	No	64	20	11.6	0.064	0.71	0.21
	Yes	No	Yes	21	80	13.4	0.087	0.62	0.36
	Yes	Yes	Yes	69	14	12.4	0.060	0.50	0.17
1935....	No	No	No	51	—	12.9	0.137	0.51	0.57
	Yes	No	No	98	—	12.5	0.043	0.66	0.15

Sources of data:

Cruess, W. V. Notes on producing and keeping wines low in volatile acidity. Fruit Products Journal **15**: 76-77, 108-109. 1935.

Cruess, W. V. Further data on the effect of SO_2 in preventing high volatile acidity in wines. Fruit Products Journal **15**: 324-27, 345. 1935.

as tartaric when the maximum permissible amount of sulfur dioxide is used. In practice the actual increase in fixed acid amounts to 0.05 to 0.10 per cent.

Antioxidative Action.—Besides its other properties, sulfur dioxide can preserve the wine from too strong an oxidation, both because of its inhibitive effect on catalysts, either enzymic or metallic, and also because of its direct reduction of oxygen. When it is used in small amounts, this antioxygen action stabilizes the coloring matter present and prevents the formation of turbidities, clouds, and sediments of various types in the wine. (See p. 39 and 126 for its effect in excessive amounts.)

Control of Fermentation.—According to Bioletti and Cruess,[38] several

[38] Bioletti, F. T., and W. V. Cruess. Enological investigations. California Agr. Exp. Sta. Bul. 230:1–118. 1912. (Out of print.)

advantages are obtained by the use of sulfur dioxide in fermentation, especially when combined with pure yeast. A more nearly perfect fermentation and sounder wines are secured. The volatile acidity is uniformly lower in wines from sulfited musts than in those from untreated musts. This fact is clearly indicated in experiments reported by Cruess and summarized in table 18; sulfur dioxide was added in the form of potassium metabisulfite. The fixed acidity is protected by the use of sulfur dioxide, and the sulfited wines consequently show a higher total acidity than the untreated. The use of sulfur dioxide or metabisulfite, by insuring a purer fermentation, increases the yield of alcohol, often by as much as 1 per cent.

Preservation of Wine.—Wines made from sulfited musts keep much better than those obtained by natural fermentations. Sulfur dioxide is useful also in preventing the development of lactic-acid bacteria during storage and thus preventing spoilage. The amount to be added to the wine, however, and the concentration at which it is to be maintained should be as small as possible in order to avoid undue hindrance to normal aging. Not more than ½ pound of sulfur dioxide should be used per 1,000 gallons of wine; this amounts to about 60 parts per million, which is usually high enough to check the development of undesirable bacteria and the formation of iron clouds.

Sources of Sulfur Dioxide.—The oldest process of obtaining sulfur dioxide consists in burning sulfur and introducing the products of combustion, largely sulfur dioxide gas, into the must or wine. This method is not used at present except in lightly sulfuring wine in tanks or casks during racking. The sulfur is first burned in the cask or tanks and the sulfur dioxide is absorbed by the must or wine as the vessel is filled. One serious objection to this method is that the sulfur which falls or sublimes into the cask may be reduced by yeast to hydrogen sulfide, a gas of objectionable, rotten-egg odor and flavor.

Liquid sulfur dioxide, the gas liquefied under pressure and held in heavy-walled steel cylinders, is being used to an increasing extent. Its advantages are purity and relative cheapness. By any of several measuring devices for dispensing the sulfur dioxide an exact amount of the gas from the cylinder can be introduced directly into the must or wine. Or a stock solution of sulfurous acid, usually containing 6 per cent, can be prepared by adding a weighed amount of gas to cold water. (See table 19 for densities of such solutions.) Such solutions are prepared by allowing the gas to bubble through water chilled with ice to below 40° Fahrenheit in a barrel, care being taken to prevent undue losses by overrapid addition of the gas. To weigh the gas used, the cylinder is placed on a platform scale and is weighed before and after the gas is drawn off into the ice water. A 6 per cent solution will contain approximately 8 ounces of the liquid sulfur dioxide per gallon of water. For musts low in total acid, this form is sometimes preferable to metabisulfites. Only fresh solutions should be used, for they lose strength in storage.

Sulfites, bisulfites, and metabisulfites of alkali metals such as potassium or sodium can be used because, when dissolved in an acid solution —must, for example—they are readily converted into available sulfurous acid. In this conversion, they neutralize an equivalent amount of the acid in the must. Sodium bisulfite is the cheapest source but is not as reliable in composition or as free from contamination by heavy metals as is potassium metabisulfite. The latter is most commonly used

TABLE 19

SPECIFIC GRAVITY OF SULFUR DIOXIDE SOLUTIONS

Sulfur dioxide	Specific gravity at various temperatures			
	15° C	20° C	25° C	30° C
per cent				
1.0	1.0060	1.0050	1.0034	1.0020
2.0	1.0112	1.0093	1.0074	1.0066
3.0	1.0170	1.0138	1.0113	1.0092
4.0	1.0223	1.0172	1.0144	1.0109
5.0	1.0241	1.0197	1.0186	1.0132
6.0	1.0282	1.0230	1.0193	1.0158
7.0	1.0319	1.0252	1.0205	1.0182

Source of data:
Quinn, D. G. Sulfurous acid in wine making. Australian Brewing and Wine Journal **56** (6):39–40. 1938.

and contains a higher percentage of available sulfur dioxide than some of the other sulfites of potassium: it contains 57.6 per cent sulfur dioxide, although only 50 per cent is usually considered to be available under practical conditions. The crystalline or the powdered salt should be dissolved in water at the rate of 8 ounces to each gallon, care being taken to see that it is completely dissolved and thoroughly mixed before being added to the must. One gallon of this solution is enough for 1 ton of grapes (see table 17). The solution may be added slowly to the crushing sump or to the stream of must as it discharges from the delivery pipe of the must line. Since the metabisulfite, even in powdered form, decreases in strength on standing, only freshly prepared solutions from the fresh dry salt are acceptable.

In using any form of sulfur dioxide, one must measure the amount accurately, apply it as soon as possible after crushing the grapes, and distribute it quickly and evenly throughout the mass. Any method that accomplishes all of these requirements is satisfactory. When using the liquid sulfurous acid solution, one can add the amount needed per ton of grapes slowly and regularly to the vat being filled or to the crushing sump by some controlled dropping device such as a large bottle fitted with a siphon. Another possible method is to distribute the sulfurous acid solution uniformly over the surface of the must at regular intervals—for example, after 1,000 gallons of crushed must has collected in the fermenting tank. Or the amount of solution required for each 1,000 gallons (see table 17) could be added after the entire quantity of must has collected in the fermenter, and the whole mass thoroughly punched down at the completion of filling.

THE USE OF PURE YEASTS

The use of selected cultures of yeasts is common in wine making, particularly in conjunction with the control of fermentation by the use of sulfur dioxide in order to render conditions favorable to the growth of the desired organisms and unfavorable to others. This practice, when properly used, results in a fermentation that begins promptly, proceeds regularly, and goes to completion in a relatively short time. A more complete utilization of the sugar occurs, which assures a better preservation of the product and an increased yield of alcohol.

According to most authorities, the fermentation should be conducted so as to favor the wine yeasts; but not all agree as to the proper method of accomplishing this result. Some enologists have been obsessed with the idea of obtaining fine wines by inoculating ordinary musts with yeasts derived from the better wine districts. Although a particular strain of wine yeasts may have some inherent flavor-producing quality, it is as idle to consider that Burgundy wines can be made by fermenting Alicante Bouschet must with Burgundy yeasts as to consider that a sauterne can be made from Muscat or Concord grapes. On the other hand, beer yeasts (commonly called *Saccharomyces cerevisiae* strains) certainly give to grape musts a cereal or yeasty flavor, whereas wine yeasts (commonly called *Saccharomyces ellipsoideus* strains) produce a fruity or vinous flavor even in sweet wort. The various strains of *Saccharomyces ellipsoideus* differ in the amount and type of desirable vinous flavors they produce.

Very probably, in the districts of Europe where wine making has been practiced for centuries, wine yeasts particularly adapted to bringing out the best qualities of the particular variety of grape grown in these districts are found in predominating numbers on the grapes at the later stages of ripening. At any rate, sound wines can be made in those regions merely by light sulfiting of the musts without the addition of yeast. In many of the wine-making districts, furthermore, when yeast starters are used, as in years of unfavorable weather conditions when the natural microflora is defective, they are prepared from the yeasts indigenous to the region.

The microflora of California grapes and wine has not been studied systematically. Holm[39] described incompletely several yeasts from samples of California grapes and has concluded that yeasts found on grapes produced in regions remote from wineries form but low amounts of alcohol and produce films, turbidity, and unpleasant flavors or tastes. Cruess[40] described species of six genera of yeasts obtained by him from California grapes. Mrak and McClung,[41] more recently, described 241 cultures of sporulating and nonsporulating yeasts obtained from California grapes and wines: those most commonly isolated were species of *Saccharomyces,* and the next most common were species of *Kloeckera, Kloeckeriaspora,* and *Hanseniaspora.* Eight genera of sporulating and seven genera of nonsporulating yeasts were reported to be present.

The true wine yeast was never abundant on grapes examined by Cruess and was usually outnumbered many thousand times by injurious microörganisms. Furthermore, as Cruess and others have found, most strains of wine yeast present on California grapes ferment certain musts only incompletely, give a lower yield of alcohol, and while fermenting form a finely divided cloud throughout the liquid. After settling, when the fermentation is complete, such yeast is easily disturbed and clouds the wine.

A natural or spontaneous fermentation due to the yeast carried into the vat on the skins of the grapes occurs in at least two stages. In the first stage, a wild yeast, *Kloeckera apiculata* (often incorrectly called *Saccharomyces apiculatus*), is most numerous. This yeast ceases to ferment when the must contains about 4 per cent alcohol; and it then gives way to the true wine yeast, *Saccharomyces cerevisiae* var. *ellipsoideus,* which completes the second stage. Other wild yeasts and bacteria occur and are more or less harmful, although some are thought to produce desirable characteristics in certain special wines.

Use of Starters.—If sufficient active starter of pure wine yeast of the proper kind is added, the undesirable organisms will be so outnumbered that they cannot act upon the must. They may be further inactivated, as previously described, if sulfur dioxide is added before the pure yeast. The must is not usually pasteurized before fermentation, although

[39] Holm, Hans C. A study of yeasts from California grapes. California Agr. Exp. Sta. Bul. 197:169–75. 1908.

[40] Cruess, W. V. The fermentation organisms of California grapes. University of California Publications in Agricultural Sciences 4(1):1–66. 1918.

[41] Mrak, E. M., and L. S. McClung. Concerning the genera of yeasts occurring on grapes and grape products in California. Journal of Bacteriology 36:74–75. 1938.

the practice has merit in certain cases of excessive contamination. If sulfur dioxide is used, the must should stand for several hours before the yeast starter is put in. White must should be thoroughly aerated after settling, either before or after the addition of an adequate starter. According to the investigations of Cruess and Bioletti, the starter is at its maximum activity when the Balling degree of the must in which it is grown has been reduced about one-half. Its efficiency does not greatly diminish until nearly all the sugar has disappeared.

Burgundy and champagne strains of wine yeasts used in California[42] are considered best for starters, because they form a heavy granular and compact sediment toward the end of the fermentation and produce satisfactory fermentations. Wines made with them clear rapidly. Yeasts are generally supplied to the winery as streak cultures on nutrient agar in cotton-stoppered test tubes or bottles. For propagation at the winery the bottle culture is preferable because of its larger size.

The yeast starter before use is increased in volume, preferably by growing in a suitable pure-culture system. It may be gradually increased in volume, with suitable precautions against infection, by successive transfers from the original culture to quantities of sterile must increasing in size: ½-pint culture, for example, being transferred in succession to 1 gallon, 5 gallons, 50 gallons, and 500 gallons of sterile must. The transfers are made at the height of activity. The smaller quantities of must are bulk-pasteurized and the larger (over 50 gallons) are sulfited before use.

A better procedure is to use a pure-yeast-propagating apparatus which consists essentially of two closed tanks equipped with steam and cooling coils, and air distributors. One tank is set above the other. Grape juice is introduced into the upper tank, pasteurized, cooled, aerated, and then dropped into several gallons of active starter in the lower tank; such an apparatus is shown in figure 3. When the must is in active fermentation in the lower tank, all but a few gallons of it are withdrawn; and fresh sterile must is then introduced into the culture vessel.

It is best to inoculate each fermenting vat with a fresh yeast starter, because transfer from vat to vat is sure to cause contamination with other yeasts. As little as 1 per cent by volume of active starter is satisfactory when the juice is clean and is fairly free from undesirable wild yeasts and bacteria; rarely is it necessary to add over 3 per cent. Too much starter should not be used, for it may produce rapid and violent fermentation during which heat may be generated too rapidly to be controlled, even by cooling.

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[42] Obtained originally in 1895 from George Jacquemin of the Institut La Claire, La Locle, Doubs, France, by the University of California.

CONTROL OF TEMPERATURE

In the opinion of most enologists, an excellent bouquet and aroma are formed by a long, gradual fermentation at low temperatures rather than by a short, quick fermentation at higher temperatures.[43] In cool

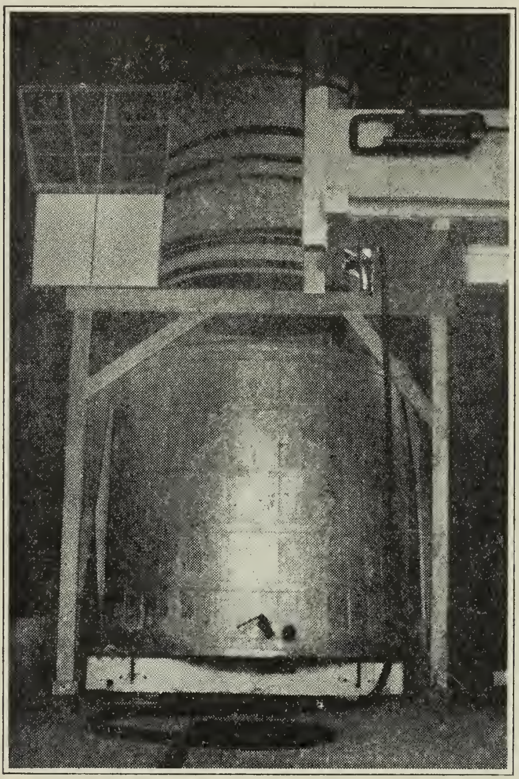

Fig. 3.—A simple pure-yeast propagating unit consisting of two redwood vats. The must is sterilized, cooled, and aerated in the upper vat and then dropped into the lower one, in which the yeast is grown.

fermentations, the yeast apparently produces more esters and other aromatic bodies. This statement also holds true for other fermented fruit products—for example, cider. At high temperatures, moreover, the yeast causes reactions unfavorable to the quality. A wine fermented at 70° to 75° Fahrenheit is smoother and fresher, with a more desirable bouquet, than one fermented at 90° to 95°. The latter, if fermented on the skins, has more color, tannin, and body because of the

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[43] Jordan, Rudolf. Quality in dry wines through adequate fermentations. 146 p. Privately published, San Francisco. 1911.

greater solubility of those substances at the higher temperature.[44] At lower temperatures, the yield of alcohol is greater, partly because of lower losses of alcohol by evaporation and by entrainment in the escaping carbon dioxide gas, and partly because of the more efficient transformation of fermentable sugar into alcohol. At high temperatures there is danger of "sticking" while considerable amounts of sugar still remain in the wine. Excessively high temperatures during fermentation encourage the growth of wine-disease bacteria and result in an undesirably high production of volatile acids. Finally, the wine obtained by cool fermentation is more easily cleared and is less susceptible to bacterial attack and spoilage.

Considerable heat is generated during alcoholic fermentation and, unless dissipated, will cause a rise in temperature of the must. The amount liberated in the fermentation has been calculated from the difference of heats of combustion for the fermented material and for the products formed. This computation is not very accurate because errors occur in combustion-heat determinations, because corrections must be made for heats of solutions of products and for gases escaping, because the concentration of reacting substances continuously decreases while that of the products increases, and because the fermentation occurs in successive stages of decomposition of sugar. The heat evolved from 180 grams of sugar consumed in the reaction $C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$ (see p. 30) has been calculated by Rahn[45a] to be 26.0 Calories (kilogram-calories) when the sugar, alcohol, and carbon dioxide are in their standard state, whereas other calculations reported vary from 22 to 33. Genevois,[45b] in a more recent calculation, has reported 28.0 Calories when the reacting substances and products are in dilute solution. Winzler and Baumberger[46a] give a calculated value of 22.5 for dextrose at a concentration of 1×10^{-4} *M*, alcohol at 2×10^{-3} *M*, and carbon dioxide gas at a pressure of 0.0003 atmospheres. The heat evolved in fermentation has been measured by a number of investigators. Of the earlier measurements, those of Bouffard[46b] are most consistent; he found the heat of fermentation of grape juice to vary from 23.4 to 23.7 Calories

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[44] Bioletti, F. T. The manufacture of dry wines in hot countries. California Agr. Exp. Sta. Bul. 167:1–66. 1905. (Out of print.)

[45a] Rahn, Otto. Physiology of bacteria. p. 27. P. Blakiston's Son & Co. Inc., Philadelphia. 1932.

[45b] Genevois, L. L'énergétique des fermentations. Annales des Fermentations 2:65–78. 1936.

[46a] Winzler, Richard John, and James Percy Baumberger. The degradation of energy in the metabolism of yeast cells. Journal of Cellular and Comparative Physiology 12:183–211. 1938.

[46b] Bouffard, A. Detérmination de la chaleur dégagée dans la fermentation alcoolique. Progrès Agricole et Viticole 24:345–47. 1895.

per 180 grams of sugar fermented. Rubner[46c] subsequently (1904 and 1913) reported 24.00, and after correcting for the formation of by-products, such as glycerin and succinic acid, during the alcoholic fermentation, he has calculated a value of 24.055, which agrees closely with his experimentally measured value. Although some European enologists consider the heat liberated in fermentation to be about 27 Calories, the majority accept Bouffard's early measurement of 23.5 Calories.

On the basis of 23.5 Calories per 180 grams of sugar, a must containing 22 per cent of sugar would rise about 52° Fahrenheit if all the heat developed by fermentation were prevented from escaping. That is, for each Balling degree of sugar in the must, sufficient heat is generated during fermentation to raise the temperature approximately 2.34°. If its initial temperature were 60°, it would reach 100° and stick while still containing 5 per cent of sugar. In practice these temperatures are not reached because heat is lost by radiation from the open surface of the fermenter to the surroundings, by conduction through the walls of the fermenter, and by loss in the evolved carbon dioxide gas. Although large volumes of gas are given off (1 liter of must containing 180 grams of sugar liberating, for example, at 95° about 50 liters of gas), the heat capacity of this gas and the amount lost by its evolution are usually insignificant. Some French enologists believe, however, that one-fifth of the heat liberated in fermentation is absorbed and eliminated with the carbon dioxide.

The temperature to which the fermenting grapes or must will rise is determined by their temperature when crushed, plus the rise in temperature due to the heat generated by fermentation, and minus the heat lost during fermentation by radiation and conduction. The warmer the grapes and the more sugar they contain, therefore, the higher the temperature will rise. The smaller the fermenting mass, the cooler the air, and the slower the fermentation, the less the temperature will rise. Cooling the grapes or must before fermentation, fermenting in vats with a large radiating surface per unit volume, and cooling the fermenting must itself are the means by which dangerously high temperatures may be prevented. Even in the cool coastal regions where small fermentation vats are used, cooling during fermentation is necessary in controlling the temperature, particularly early in the vintage season. Where large fermenting vats of 3,000 to 10,000 gallons' capacity are used for fermenting dry table wines, the fermenting must has to be cooled artificially, even if the grapes are cool when crushed.

[46c] Rubner, Max. Die Umsetzungswärme bei der alkoholischen Gärung. Archiv für Hygiene 49:355–418. 1904.

Rubner, Max. Die Ernährungsphysiologie der Hefezelle bei der alkoholischen Gärung. Archiv für Anatomie und Physiologie, Physiologie Sup. 1912:1–396. 1913.

Except in the hottest weather, the heat lost by radiation in ordinary open fermentation vats not exceeding 3,000 gallons' capacity is about 50 per cent of that generated by fermentation. In very hot weather and in larger vats (up to 10,000 gallons' capacity), the loss may be no more than 33 per cent.

The amount of cooling necessary has been calculated by F. T. Bioletti[47] as follows:

Let
S = Balling degree of must (approximate sugar content),
T = temperature of contents of vat,
M = maximum temperature desired, and
C = number of degrees Fahrenheit necessary to remove by cooling.
Then
$C = 1.17° S + T - M.$

Suppose it is desired to ferment out a must of 24° Balling, initially at 70° Fahrenheit, so that 80° will not be exceeded during fermentation. Then $S = 24$, $T = 70$, $M = 80$, and

$C = (1.17° \times 24) + 70° - 80° = 28° + 70° - 80° = 18°$ Fahrenheit.

That is, in this case, if all cooling is done before fermentation begins, every gallon in the vat must be cooled to 18° F below the initial temperature (70°) in order not to exceed a maximum of 80°. This estimate is on the basis that heat equivalent to half the actual temperature rise of 2.34° per degree of sugar fermented is dissipated into the surroundings. In practice, however, this loss is somewhat less, and about 1.5° to 1.8° of heat per degree of sugar must be eliminated by cooling instead of 1.17°.

Cooling must not be too extreme and should not be carried out late in the stages of fermentation, or fermentation will be too prolonged. It is better to cool the must initially, if necessary, to a point some 10° F below the maximum temperature desired and then to cool again at the height of the fermentation, when the Balling degree has decreased to approximately half its initial value, and the yeast cells are more numerous and more active. At this stage, cooling will have less retarding effect upon fermentation. The temperature of the must at this stage should be reduced about 1.5° for each degree Balling so that the final temperature will not exceed that at this point. It is desirable to cool even further so that the maximum desirable temperature is not exceeded.

A uniform low fermentation temperature is best, and can sometimes

[47] Bioletti, Frederic T. A new wine-cooling machine. California Agr. Exp. Sta. Bul. 174:1–27. 1906. (Out of print.)

be obtained by means of cooling coils through which cold water or other refrigerant is passed. These coils must be properly placed and large enough for adequate temperature control. More positive results are obtained by passing the must through tubular heat interchangers in which it is cooled by indirect contact with a suitable refrigerant. The refrigerant may be cool well water, ice water, cold brine, or some other suitable product. It may be sprayed over the coils through which must is pumped, or conveyed in outer tubes past inner tubes of must. Any refrigerator used should be constructed of corrosion-resistant metals. To facilitate pumping through the refrigerator, the must should be drawn off through a screen, to separate out skins and seeds into a sump. It may then be sent through the cooler. In emergencies cooling may be accomplished by adding ice directly to the fermenter, although this dilutes the must, and should be used in but small quantities.

The temperatures reached in the fermenting vats should be noted frequently. The rise is greater in open red-wine fermenters than in closed white-wine fermenters because heat is lost more slowly from the surface of the former: the pomace tends to rise to the top, forming a semidry "cap." One should take the temperature of the wine just below the cap after punching. The heat is highest here because of the insulating effect of the cap. The reading should be taken on a long-stemmed, easily read thermometer (fig. 4) whose bulb is immersed in the vat. Temperatures read on thermometers attached to hydrometers or on small thermometers pulled out of the vat to be read may be low by as much as 10°. Removing a sample from the vat with a wine thief, transferring it to a hydrometer jar, reading the hydrometer, and then reading the thermometer in the hydrometer, is not the proper way to take the temperature of wine. Long-stemmed thermometers with an indicating dial are available for winery use. In the larger plants, recording thermometers are useful, since they furnish a permanent record of the temperatures attained in fermentation.

Fig. 4. Long-stemmed indicating thermometer suitable for taking the temperature of must in fermentation.

Cold weather during the late fall or early winter may result in sticking because of lowered temperature. In this case, in order to complete the fermentation, it may be necessary to warm the wine by using a tubular heat interchanger such as a pasteurizer.

WINERY DESIGN, CONSTRUCTION, AND SANITATION [48]

DESIGN AND CONSTRUCTION

Location.—The winery should have a convenient and suitable location. An abundance of cool water is necessary. Adequate drainage and sewage facilities must be at hand, especially when considerable distillery slop must be disposed of. Industrial sewage disposal, where available, is most satisfactory, for it relieves the winery of all responsibility. Disposal of the wastes in rivers and near sources of drinking water is undesirable, if not illegal. Proximity to vineyards and to transportation facilities—railroads, main highways—must also be considered in selecting a site. One should weigh the natural climatic factors, selecting, if possible, the cooler localities as better for both fermentation and storage. Wineries near cities should be placed on the opposite side of town from which the prevailing wind blows.

Materials of Construction.—The materials used in construction should provide sufficient insulation for satisfactory maintenance of inside temperatures, and should not be too expensive. For these reasons, concrete, stone, brick, and hollow tile are preferred. If in an earthquake zone, the construction should be earthquake-proof.

Caves provide cool temperatures suitable for the storage of wines, but are seldom obtainable in this state.

Wineries in warm regions should have an insulated cool storage cellar and a cool fermentation room. The cooler the storage, the better the preservation of the wines during the summer months. If an aboveground storage space is used, one can obtain considerable cooling by opening the doors at night and closing them by day.

Arrangement.—A winery producing red and white table wines consists essentially of (1) a fermenting room with adjacent crushing space, (2) a storage cellar with an adjacent operating space, and (3) a bottling room with adjoining office and laboratory. A machinery room for the boiler and refrigeration equipment, and a cooper shop will usually be necessary.

The particular arrangement of each of these units depends on the size, location, and type of winery. Considerable segregation occurs when the winery is large enough to permit separate fermenting rooms for red and for white wines. This arrangement is highly desirable: it reduces the possibility of tainting the white wine with any of the red-wine equipment; it makes for more efficient operation because separate crushers, presses, vats, hoses, and pumps can be kept for the white wines.

[48] General references on this subject are listed on page 133.

The winery should be functionally designed; that is, the wine should travel by the most economical route, especially in the handling of the must and pomace in the fermenting room. Handling is facilitated if the crusher-stemmer, presses, pomace lines, drains, tanks, and the like can be used without interfering with each other and can be thoroughly

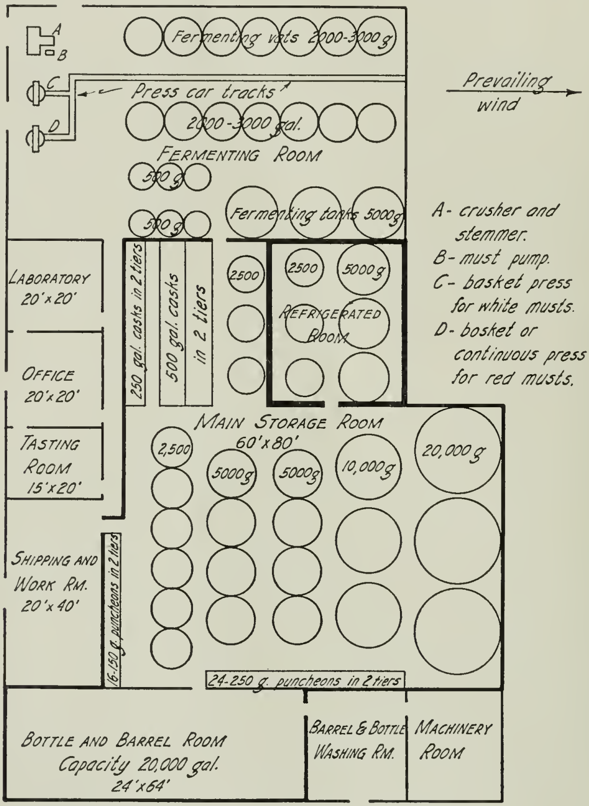

Fig. 5.—Schematic floor plan of a winery.

cleaned in the simplest fashion. The actual layout of a winery depends upon local conditions as well as upon the general principles just mentioned; the experience of plants of similar size and type should be investigated. Modern Algerian wineries for bulk wines are constructed with moderate-sized, glass-lined, concrete tanks, two or three tiers high, forming the wall on three sides of a work space; this economizes construction and facilitates operation.

A suggested layout for a winery handling less than 1,000 tons of grapes annually is given in figure 5. Only table wines are to be produced and no still has been provided. About one third of the total production is to be white wines and about one half of the total production is to be aged for three years. Over two hundred thousand gallons' storage capacity are therefore provided. A refrigerating room and an insulated main storage room are indicated. Such a layout with the addition of suitable equipment—heat exchangers, filters, corking equipment, and the like—should be capable of producing both ordinary bulk and fine bottled wines. Attention is directed to the size and adequacy of the fermenting room. Sumps are used widely in larger wineries in both the fermenting and the storage room, for they facilitate the blending and transfer of must and wine.

Size.—The proper size for the winery depends on the aims and requirements of the proprietor. Neither a large nor small winery can guarantee quality wines unless the factors influencing quality—such as selection of proper grapes and good fermentation—are recognized and controlled.

The fermenting room should be large enough to meet the needs of a fermenting season lasting from 6 to 12 weeks. The capacity of the vats should be sufficient to provide for uncrowded operation of crushers and presses. The size of the storage room will depend on the average aging period used. If the average time is three years, an annual production of 100,000 gallons will require over 300,000 gallons of storage space. If, however, the wines are aged only a year, the storage cellar need be but little larger than the size of the average annual production.

Ventilation.—High ceilings and adequate window or vent space are desirable in the fermenting room to remove volatile fermentation products and for cooling. The bottling room should be light and airy.

EQUIPMENT

Materials.—All materials with which the musts and wines come in contact not only should be resistant to corrosion, but also should add no undesirable flavors, aromas, or metals to the musts or to the wine. The finished wine, particularly, must be guarded against metallic contamination during storage. In the small winery these requirements could be met by wooden crushers, presses, vats, casks, and buckets, and glass bottles. The use of metal crushers, stemmers, and must lines has led to much iron and copper pickup, while the calcium pickup from new concrete tanks is considerable. Since these cause various disorders in the wine, such as clouding, off-flavors, and off-aromas, they should be avoided. Unfortunately the simplest solution, the use of noncorrosive metals, is expensive; but as Mrak and his associates[49] have shown,

[49] Mrak, E. M., L. Cash, and D. C. Caudron. Effects of certain metals and alloys on claret- and sauterne-type wines made from vinifera grapes. Food Research 2(6): 539–47. 1937.

moderately resistant metals are satisfactory provided their contact with the must or wine is not prolonged. Since not all the places where grapes and wines touch metal surfaces are equally corrosive, different metals may be used with success at different points. The volume of wine passed through or over a given metal surface is also important. Local conditions also vary with the acidity and pH of the musts.

Oak, the preferred material for wine containers (figs. 6, 8, 10, and 14), is expensive, especially for large-scale installations. Redwood has been utilized extensively in California, and many tanks in use for over a quarter of a century still appear in good condition. Redwood vats are also used for red-wine fermentation, as shown in figure 12 (p. 69).

More recently, concrete has been popular. When glass-lined, it makes a highly satisfactory container for wines which are to be kept from the air—for example, champagne stock. Since, however, most California cement tanks have not been glass-lined, there has been much difficulty in securing a suitable lining for those used in storage of ordinary bulk wine. Concrete vats, which may be lined or unlined, are also used for red-wine fermentation.

Floors, Piers, and Services.—Waterproof, concrete-surfaced floors are desirable in wineries, at least in the fermenting room. The floors throughout the plant should be well sloped for drainage; drains beneath the lower valves of the tanks are useful. The drains should have well-rounded bottoms to prevent accumulation of materials, should be covered with an iron grating, and should be numerous enough and large enough to take care of the maximum drainage load. Wooden and dirt floors accumulate bacteria from spoiled, spilled wine, are difficult to clean, and serve as sources of contamination. There should be no inaccessible places where dirt, pomace, or wine can accumulate.

The fermenting and storage tanks should be set on fairly high concrete piers (fig. 6), which will facilitate cleaning under the tanks and periodic inspection of the bottoms of the vats and casks.

A high-pressure cold-water supply, with many easily accessible outlets in all parts of the winery, is essential. Steam and hot-water outlets will also facilitate the cleaning and heating of tanks.

Permanently installed, corrosion-resistant or suitably lined pipes from the fermentation vats and tanks to the sumps, from the fermenting room to the storage room, and between tanks are provided in some wineries. These should be self-draining and arranged for easy cleaning with steam, water, or antiseptic solutions.

Frequent electrical outlets for current of various power loads are a great convenience in winery operation.

Crushers and Stemmers.—If the winery is small, the crusher and stemmer can be placed in one corner of the fermenting room. It should then be set so that the stems fall outside the room or can be easily removed. Moderate-sized wineries should construct an adjoining shed for

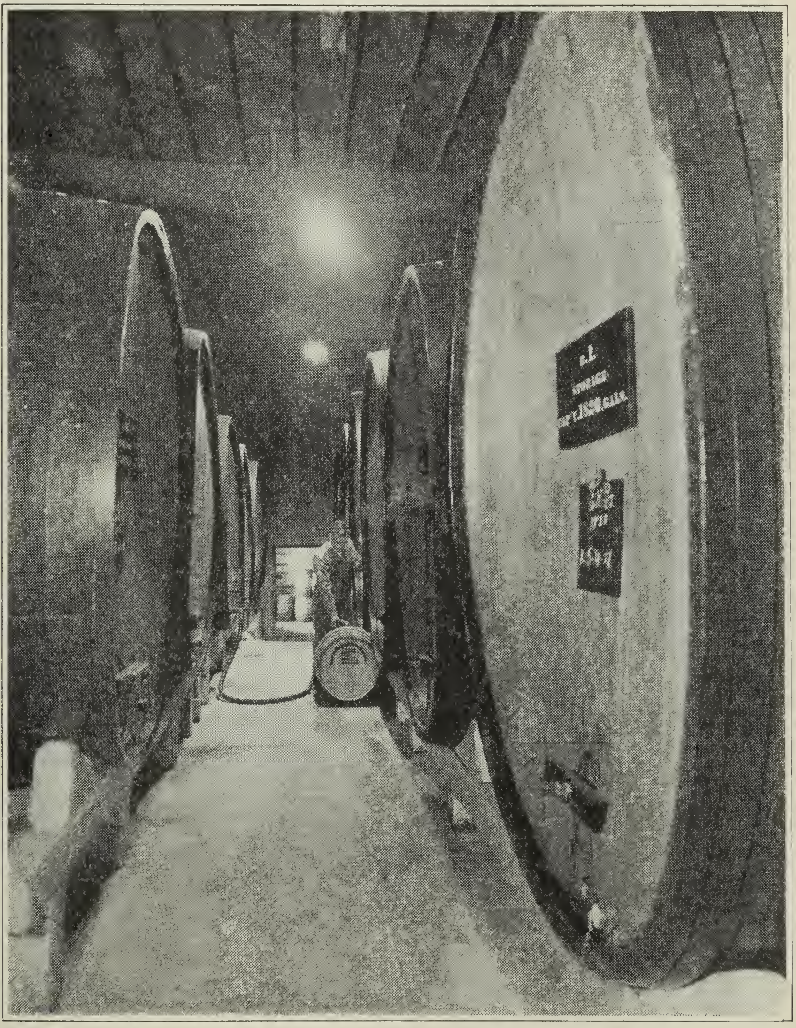

Fig. 6.—Filling a 50-gallon barrel from an 1,800-gallon oak oval storage cask. (Photograph by courtesy of the Wine Institute.)

this equipment; very large wineries, a separate building. When the volume handled per day is small, the grapes can be dumped directly into the machine. But if this arrangement slows down the crushing so that grapes cannot be unloaded rapidly, then a special stemmer-crusher station should be provided—usually a small shed a short distance from the fermenting room. A concrete base for the machinery should be built with an unloading platform on one end of the crusher that provides for simultaneous unloading from both sides. The platform should be well sloped to the conveyor, and the conveyor itself solidly built in an easily cleaned trough. Considerable juice for use as distilling material can be collected, provided the whole platform has adequate drainage. Where more than one crusher is needed, separate crushers for red and for white grapes should be maintained.

Two general types of crushers are used in California. The most common has two grooved metal rollers which crush as well as tear the grapes between them while revolving in opposite directions at the same or different speeds. The rollers must be set far enough apart so that the seeds are not broken, but close enough to crush all the fruit. The proper distance between them depends on the variety and maturity of the grapes, and on the season. The crushed grapes and stems drop down into one end of a perforated cylinder, where they are separated from each other by revolving metal paddles. The stems are ejected at one end; and the must collects in a sump, from which it is pumped.

Other crushers have very rapidly moving metal paddles set in a more slowly revolving cylinder. The grapes are knocked against the sides of the cylinder, crushed, and separated from the stems. The must falls through the holes in the cylinder, and the stems continue out through the end. Very thin-skinned, juicy varieties are crushed easily; overripe, tough, thick-skinned ones, with more difficulty. The revolution of the paddles may be speeded, and up to a point this arrangement is helpful in securing a greater percentage of crushed fruit.

Crushers can be built of noncorrosive metals. Mrak and his associates[50] and Searle[51] have made extensive tests with various kinds. Stainless steels, 18.8 alloy, Inconel, aluminum alloy 76, Durimetl, and certain metalized metals withstood corrosion satisfactorily. In some cases, the lack of corrosion may have been due to tartrate deposition, which prevented contact between the metal and the liquid. The metals showing the least effects on the wines were Duriron, Durimetl, Inconel, Allegheny C, aluminum-bronze, and monel metal. If the various metals are tested at points where the must and the wine will touch them, the metal best adapted to withstand corrosion at that point may be selected.

The must is pumped from the crusher, through a must line (fig. 7), to the fermenting tanks. Wooden pipe lines, though sometimes used, have an inconvenient tendency to crack. Stainless steel or glass-lined

[50] Mrak, E. M., D. C. Caudron, and L. M. Cash. Corrosion of metals by musts and wines. Food Research 2(5):439–55. 1937.

[51] Searle, H. E., F. L. LaQue, and R. H. Dohrow. Metals and wines. Industrial and Engineering Chemistry 26:617–27. 1934.

steel is preferable to iron or copper. The must line should be easily flushed and drained. As far as possible, it should be free of tees and elbows where liquid or trash can accumulate. The inside of iron pipe may be coated with protective paints or lined with glass. Several resistant linings, free from objectional flavors and tastes, are available for coating pipes. They should, however, be made carefully, and the lining examined periodically for cracks or other imperfections. Individual tests should be made under winery conditions, especially with respect

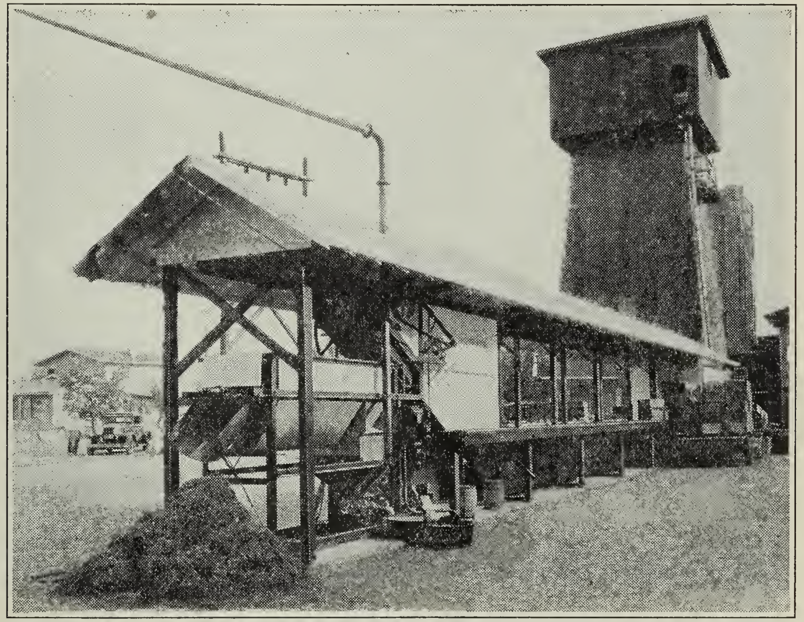

Fig. 7.—Crusher and unloading platform. Note the stems in the foreground, the must line leading from the bottom of the crusher overhead to the fermenting room, and the trucks unloading on both sides of the platform. (Photograph by courtesy of the Wine Institute.)

to the durability of the paint, its protective properties, and its effect on the wine.

Types of Containers.—Straight-sided open containers are called "vats" and may be constructed of oak, redwood (fig. 12, p. 69), or concrete (fig. 9). Similarly constructed containers with a top are called "tanks" (fig. 10). Tanks are constructed in varying sizes, mainly of redwood, of capacities of over 1,000 gallons.

Barrels, casks, and pipes have a bulge in the side due to the fact that in construction the staves are made larger in the middle than at the ends to strengthen them. They are usually made of white oak. Barrels (fig. 6) are constructed in varying capacities from 3 to 50 gallons; the smaller ones are known as "kegs." Containers of the 100- to 140-gallon size are known as "butts," "pipes," "puncheons" (fig. 8), or "casks," depending on their shape and country of origin. Some casks are constructed in an oval shape and are known as ovals (figs. 6, 8, and 10). Oak casks are made in sizes up to about 3,000 gallons. Larger cooperage is usually made in the form of a tank (fig. 10).

Fermenting Vats and Tanks.—Large fermenting vats (over 2,000 gallons) are not desirable for the better wines because they involve

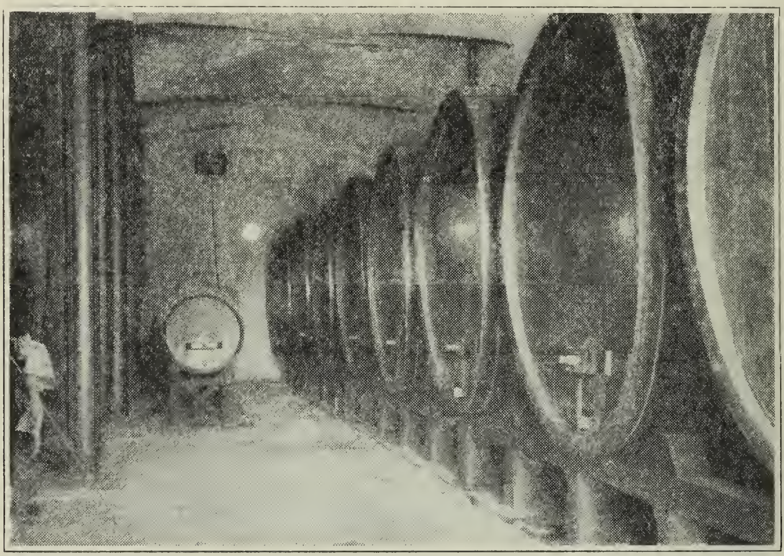

Fig 8.—A view in a typical storage room, showing the installation of oak ovals and a small puncheon in the background.

difficulties in controlling both the quality of the fruit used and the temperature and rate of fermentation.

The most recently constructed fermenting vats have been mainly of concrete (fig. 9). These are more economical of space and are easy to keep in good condition between vintages. They can be neatly arranged in rows, with a properly constructed pomace conveyor line between the rows—either on the floor or preferably at the level of the top of the vat. In the small winery, however, where movable basket presses on trucks are used, the pomace is just as conveniently transferred directly from the fermenting vats to the presses.

At present, closed concrete containers are sometimes constructed for fermenting red wines. These, which are common in Algeria, have the advantage of complete submersion of the cap and, besides, can be used for storing ordinary bulk wines at the end of the vintage season. Concrete vats are ordinarily not specially lined but should be smooth-finished. (See also page 63.) If concrete containers are to be used without protective coatings, they should first be treated with a strong 5 to 10 per cent solution of tartaric acid. Coating the fermenting tanks with various paints has also been attempted.[52] Such paints should be free of lead and linseed oil, must not flake, and should not permit the wine to pick up too much calcium. Concrete containers, aside from their economy of

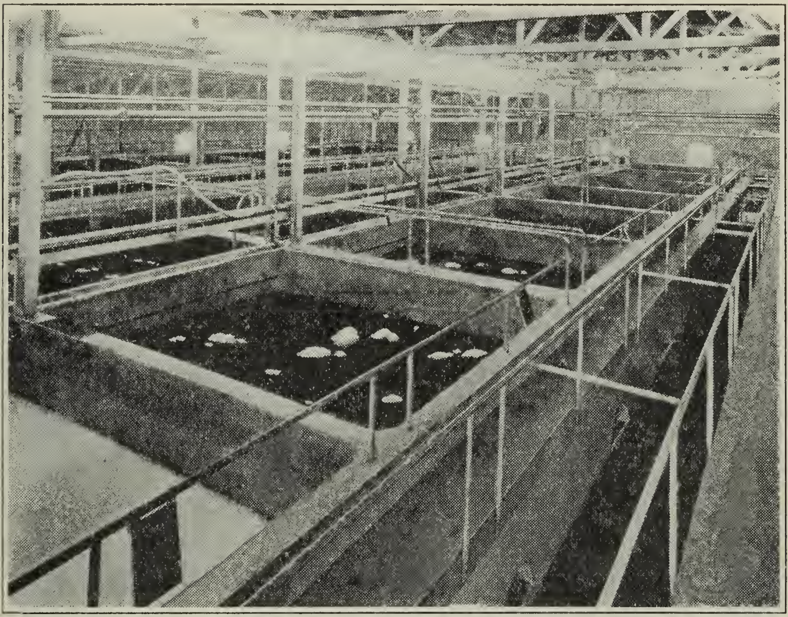

Fig. 9.—Concrete fermenting vats with temperature control. Note the pomace conveyer between the rows of vats and the covered fermentation charts for keeping record of temperature and Balling degree of the must. (Photograph by by courtesy of the Wine Institute.)

arrangement, are permanent and require little upkeep. But if the inside surface does not stay smooth, they may become difficult to clean and may actually lodge undesirable organisms in the crevices.

Despite the popularity of concrete, redwood is still a more widely used material for fermenting vats. The wooden vats last for many years. The rate of heat loss from them is usually greater than from the concrete, so that the temperature is somewhat more easily maintained. This is due to the readier heat radiation into the surrounding air both from the surface and sides because of their arrangement, shape, and larger ratio

[52] In Switzerland, a black asphalt-like wax coating known as "Ebon" is very successful.

of surface to volume. Besides, they require a smaller initial outlay. Ordinary redwood tanks and oak casks are used in fermenting white musts.

To facilitate separation of wine from pomace and the withdrawal of wine from the fermenters, the floor should be sloped to a central or side drain and a slatted false bottom installed. A V-shaped upright trough at one side is convenient for withdrawing wine or fermenting must.

Special arrangements of racks for submerged fermentation are discussed on page 70.

Fig. 10.—Storage containers: oak tanks in the background, ovals and puncheons in the foreground.

Having cooling coils for cold water, brine, or other refrigerants in all the tanks is more convenient than having only one or two sumps with such coils. Cooling coils in the fermenter should be located close to the walls, constructed of resistant metal, and periodically examined for leaks. Some wineries, however, pump the fermenting must directly through cooling coils.

If conveyors are used to remove the pomace from the vats, the press should be placed in line with the conveyor. Basket presses are probably most simply operated by having them on tracks that run between the vats. A continuous press, however, is usually not movable and must be placed in a permanent position. The pomace should be disposed of as rapidly as possible. Under no circumstances should it stand in or close to the fermentation room, for it rapidly acetifies, and the fruit flies quickly carry the germs from the pomace pile to the clean fermenting vats.

The Storage Room.—The problem of the storage cellar is to keep the wine out of contact with air and to permit it to age normally. The redwood tank, the most generally used storage container in California, is satisfactory for all except the highest-quality wines, for which oak puncheons and ovals are recommended (fig. 10). Red wines may be kept in properly treated barrels without loss of quality; indeed, for their best aging, they should not be placed in containers of very large size.

Concrete tanks with various types of linings have been used for ordinary dry wines. No completely satisfactory conditioning material for concrete storage tanks has been found to date. Although Bass Heuter black enamel was found by Cruess [53] to be the best covering for concrete, its use nevertheless permitted a considerable calcium pickup by the wine.

After a year or two, the tartrates will have to be scraped off the sides of such tanks, and the walls washed with a hot soda-ash solution. These containers have the advantage of occupying less space. Since, however, the wine in them has less contact with the air than through wooden casks, there is not only less evaporation but also less aging. If the concrete tanks have not been properly lined or treated, the wines may show considerable calcium pickup, and the acidity may be reduced so that the wines taste flat and vapid; such tanks should therefore not be used for the wines of better quality or for aging and particularly not for wines containing much free sulfur dioxide.

WINERY SANITATION AND OPERATION

Preparation and Storage of Containers.—New oak casks and redwood vats and tanks must be treated before wine is placed in them, usually by spraying a hot solution of soda ash, 2–5 per cent, over all the interior surface. Small containers may be completely filled with the hot solution. This extracts much of the soluble bitter, oak-flavored constituents that would later taint the wine. The container is then washed with a dilute acid solution, followed by a second soda solution and finally by several washings with plain water. Some prefer to use hot water as well as the hot soda solution for conditioning. Clean distilling material, if available, makes an admirable liquid to place in the new container to complete the conditioning. The outside of all cooperage should be treated, usually by spraying with linseed oil. The cask-

[53] Cruess, W. V., T. Scott, H. B. Smith, and L. M. Cash. A comparison of various treatments of cement and steel wine tank surfaces. Food Research 2(5):385–96. 1937.

borer (*Scobicia declives*) attacks mainly oak containers and is occasionally found in redwood tanks that contain wine or fermenting must. Since it works mainly in the light, containers in a dark place are less liable to be attacked. A hot, strong solution of alum applied to the outside of the casks and followed, when dry, by the usual linseed-oil spray will give adequate protection. To prevent rusting, hoops should either be painted or galvanized.

Used cooperage should not be utilized without proper conditioning to avoid losses in both quality and volume of wine. Often, especially where the casks leak because of cracked staves, they should be recoopered. In this process, the staves are scraped; and sometimes a new head is built. Although recoopering is expensive, it prevents the use of contaminated containers and frequently saves the winery much subsequent trouble from leakage and spoilage. If the winery chooses to treat the bad cooperage itself, the inside should be carefully examined for molds, cracks, and other defects. Any growths should be scraped, as they can rarely be washed off completely. A hypochlorite solution (containing from 500 to 1,000 parts per million of available chlorine) should then be sprayed over the inner walls of the container, or filled into it .This should be followed by several washings with water. If the container still smells unsatisfactory, steam should be tried, care being taken not to warp the heads and the staves. A second application of the hypochlorite solution may be necessary, or a combined hypochlorite-steam treatment. In any case, all traces of hypochlorite must be removed. Inert and impervious plastic or composition wax linings have proved useful in recovering old or badly leaking tanks.

A dilute, hot soda-ash solution effectively neutralizes any vinegar present in used barrels and, if followed by a steaming and washing, usually places the barrels in good condition. The use of hot soda-ash solution of too high a concentration or for too long a time, however, causes undesirable deterioration of the wood. For very badly spoiled cooperage, several preliminary treatments with hydrogen peroxide, potassium permanganate, or neutral oils may be necessary.

Storing empty cooperage is often a difficult problem. The hot, low-humidity conditions of California rapidly dry out the empty containers, which frequently fall apart. If tanks, casks, or barrels are to be kept empty, the staves should be tightened occasionally and never allowed to fall apart. If sulfur is burned in the barrels or if sulfur dioxide is introduced, they should remain in a sanitary condition. Care must be taken, however, not to use too much sulfur dioxide, which apparently is absorbed by the wood and may be difficult to remove even with several washings of water. If the excess is not eliminated, too much may be absorbed from the wood by the wine.[54] Open fermenting vats, when not in use, are frequently painted with a dilute solution of lime.

Since it is so difficult to keep wine containers, especially small ones, in an empty condition, many wineries now fill them with various preparations—for example, a dilute hypochlorite solution (250 parts per million). Saturated lime water, though satisfactory for short intervals, has only a limited period of effectiveness in preventing contamination. A dilute solution of sulfuric acid and potassium metabisulfite (½ pound of concentrated sulfuric acid and ½ pound of metabisulfite per 100 gallons) will also maintain the containers in good condition, but the cooperage should be inspected occasionally to make sure that evaporation has not occurred, which would permit the drying-out of the staves. Fluosilicic acid and other compounds containing fluorine should not be used in the winery.

Maintenance.—Much of the difficulty in keeping a winery clean is caused by poor arrangement and by inaccessibility of corners and crevices. The floors should be scrubbed regularly and disinfected at intervals with a dilute solution of hypochlorite. Wine spilled on the floor should be immediately washed away. The use of sawdust to absorb spilled wine is most undesirable. Surfaces on which wine has spoiled should be scrubbed, washed with a strong hypochlorite solution, and rinsed off with water.

Improper care of equipment is, however, perhaps the commonest source of contamination. Presses, filters, hoses, pipes, and tank cars are all difficult to clean completely. A mere washing with water is rarely adequate. Under the warm climatic conditions of California, any wine or must left in the equipment rapidly spoils, and becomes a source of contamination for the whole winery. Therefore, after use, the equipment should be dismantled as completely as possible, thoroughly washed with water, followed by live steam or solutions of hypochlorite, and then rinsed with clean water and drained. Hoses should be placed on special sloping racks instead of remaining on the floor. Thorough cleansing and sterilization are especially necessary after removing, isolating, or disposing of spoiled or contaminated wine. In general, every surface with which wine comes in contact can be considered a source of contamination and should be treated as such before and after use.

Care of Crushers and Stemmers.—Stemmers and crushers should be carefully checked for mechanical defects. A breakdown during the vintage season can be a serious inconvenience. Any parts that can be painted should be covered with a good lacquer or with acid-proof var-

[54] Wanner, E. Beiträge zur Frage der Ueberschwefelung von Wein. Wein und Rebe **20**(9, 10):267–92. 1938.

nish. The must lines, must pumps, and other equipment used in these operations should be examined and placed in complete working order.

During the season, the conveyors, crushers, and must lines should be kept scrupulously clean. They should not be allowed to stand more than a short time with must in them. After use they should be washed out and properly drained.

DIRECTIONS FOR MAKING RED AND PINK TABLE WINES[55]

HARVESTING AND TRANSPORTATION OF GRAPES FOR RED WINES

The grapes should reach the winery in as nearly as possible their original condition and should be crushed promptly after harvesting.

Picking.—Grapes for red table-wines should be picked when they have reached a Balling of not over 23° or 24°. Rarely, if the Balling exceeds 20°, is the acid content of the grapes too high for making dry red table wines in California. But often, if it is over 24°, especially with certain varieties, the grapes have a total acid content too low for making satisfactory dry red table wines. In warm years, for varieties such as Zinfandel and Petite Sirah, the picking should be started when the Balling reaches 20°, because at higher sugar contents there will be numerous dried berries in the fruits, which markedly increase the apparent alcohol yield of these varieties.

Since a winery is obviously unable to crush its whole vintage at once, it must coöperate with the vineyardist in arranging a picking schedule. The varieties that ripen earlier, as determined by field tests, should be harvested first. The idea that the vintage should start at the same time every year is erroneous even for climatic conditions as uniform as those in California. In the warm seasons, most varieties can be harvested two to four weeks earlier than usual. It is better to start the picking too early rather than to pick a large percentage of the crop too ripe. Another solution to the problem of proper harvesting is to increase the size of the fermenting room so that a larger percentage of the crop may be handled at one time.

The delivery of grapes to the crusher in a cool condition is recommended. It may be managed either by picking grapes very early in the morning and moving them immediately to the crushers, or by allowing those picked in the afternoon to cool overnight in unstacked boxes in the vineyard. In the latter case, their condition will be less satisfactory, because of the delay, than if they were crushed immediately and the musts properly cooled.

Most picking in California is done with knives. Although these may

[55] General references on this subject are listed on page 134.

be somewhat faster and less tiring than shears, they do not allow the picker to remove rotten berries and other waste from the cluster; and they frequently slash the fruit so that juice escapes, which may cause fermentation or growth of spoilage organisms before the grapes reach the crusher. As a rule, however, they are satisfactory when carefully used, as long as the fruit is in good condition and is delivered to the winery immediately. Shears are advisable if the grapes are to be used for the best-quality wines or if the clusters are in poor condition, since they permit trimming out the undesirable parts of the clusters. Selective picking and careful handling bring the grapes to the wine maker uninjured. Moldy clusters and rotten fruit obviously should not be harvested, since they tend to lower both the quality and soundness of the wines. The careful hand-sorting of the fruit to remove diseased berries, which is practiced in certain European districts, partially has for its object the removal of the undesirable microflora present in such berries.

Second-crop grapes are present in a few varieties and, if the first-crop grapes are overripe, are useful in raising the acidity and lowering the sugar content; they should in this case be picked along with the overripe grapes.

The boxes must be as clean as possible. During the picking season they should be washed and sterilized occasionally with live steam, especially after being used to transport the grapes over long distances.

The best table wines are produced when the winery has a constant source of quality grapes from year to year. When a limited number of varieties are received, the winemaker becomes familiar with their characteristics and peculiarities and can handle each to the best advantage.

Transportation.—Wine grapes moved long distances are usually suitable only for making distilling material. If shipped for use in wine, they should be placed in boxes (fig. 11) and not in gondola trucks. Such trucks are particularly undesirable for thin-skinned, juicy varieties or for overripe and slightly spoiled grapes because of loss of juice, spoilage during transportation, overheating, and iron contamination.

WINE-MAKING PROCEDURE FOR RED WINES

Crushing.—Every effort should be made to sort the varieties and qualities of grapes into their proper types or blends before crushing. Contamination of good with less-sound grapes should not be practiced.

The best time to blend the grapes that should be used for making certain nonvarietal types of wines is during crushing. Although there is not the same exact control over the composition when the grapes are mixed at the crusher as there would be with the resulting wines, such blending is useful for making minor color corrections or for balancing a must for proper fermentation; and apparently the blend is smoother if the grapes ferment together than if the wines are mixed.

Fermentation.—The fermenting tanks should not be completely filled. A tank originally three-fourths full will later rise during fermentation nearly to the top. An approximate figure for the space required for 1 ton of crushed grapes is 26 cubic feet.

Usually, before adding sulfur dioxide, one should remove a sample of the must for testing its Balling degree and the acidity. These determinations will be helpful in deciding how much sulfur dioxide to add and what other corrections should be made upon the must.

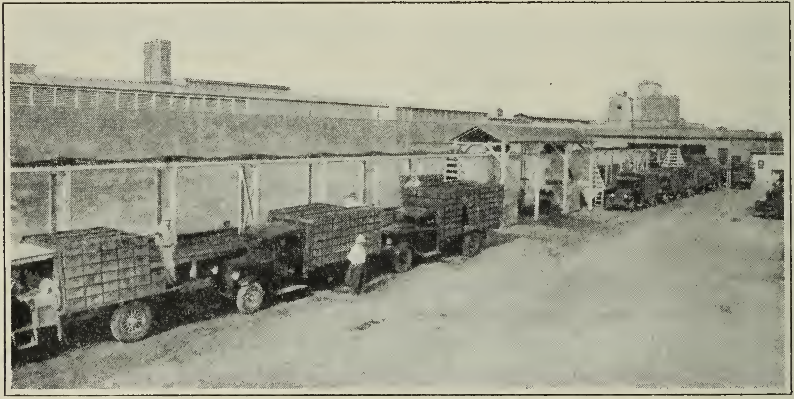

Fig. 11.—Delivering grapes to winery in boxes. Note the two crushers with a conveyer system for each. (Photograph by courtesy of the Wine Institute.)

The reasons for adding sulfur dioxide and the amounts to use under different conditions have been discussed (p. 39). Usually 15 ounces of liquid sulfur dioxide per 1,000 gallons of must will be sufficient. It may be added during the crushing if the sump, the must pump, and the must line are made of noncorrodable material; but ordinarily it is introduced into the vats during filling or immediately thereafter. If added to the full vat, the must will probably have to be pumped over in order properly to distribute the sulfur dioxide.

Several hours after sulfiting, the pure-yeast culture (p. 45) should be added and also thoroughly mixed with the must.

The Balling degree and the temperature should be taken at least twice daily until the time for pressing. One should make the temperature reading, after punching down the old cap, by means of a long-stemmed, metal-encased thermometer inserted directly through the cap. (See fig. 4, p. 52.)

The maintenance of a good set of records, although often somewhat difficult in the rush of the vintage season, is of great value. An easily referred-to record of the Balling degree and temperature can be written directly on the vat; but there should also be a permanent record of the source and type of grapes in the vat, the original total acid, the amounts of sulfur dioxide and pure yeast used, the number and times of pumping over, and the Balling degree and temperature at various stages of the fermentation.

Figure 12 shows a fermenting room with red must in redwood vats.

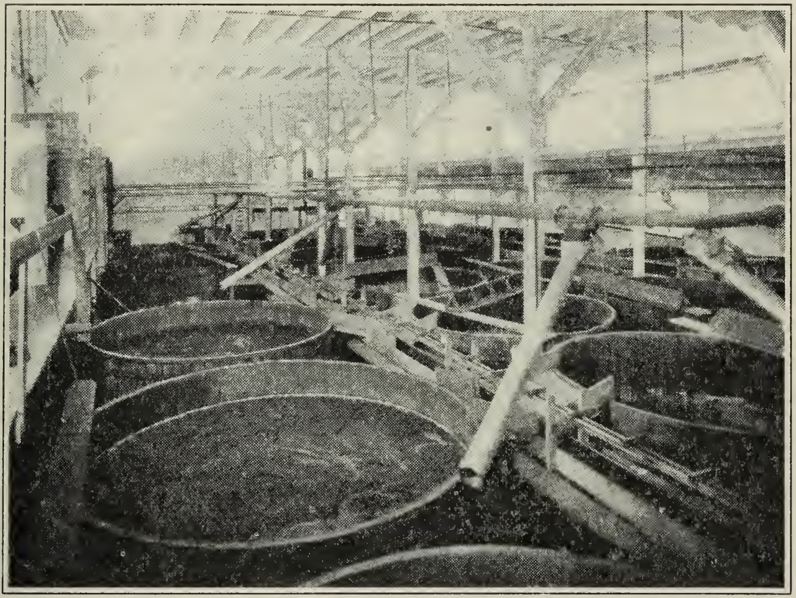

Fig. 12.—Fermentation room showing redwood vats containing red musts, conveyor system between vats, and must line with movable must distributing pipes. Note also the wooden drainage devices on top of the empty vats in the background. (Photograph by courtesy of the Wine Institute.)

In conducting red-wine fermentation, the control of the cap is a major problem. Unless properly managed, the extraction of color and tannin will be inadequate and the cap may become a source of spoilage. *At least* twice a day the cap should be punched down, or liquid from the bottom of the vat should be drawn off and pumped over it. In dry, hot climates the cap dries out rapidly, and acetification takes place within a short time. In addition, since the color is mainly in the skins, unless the cap is punched down, there will be a color deficiency in the wine. In the early stages of fermentation, punching the cap down also has the beneficial effect of aerating the must, but this is undesirable in the later periods. Consequently very active punching down or pumping over should be mainly restricted to the period before the peak of the fermentation.

During the fermentation, there will usually be a steady rise in temperature. Where plenty of cooling equipment is available, the cooling should be started well before the critical limit (p. 48) is reached. The equipment for this and the amount of cooling needed have been previously discussed. Towards the latter part of the season, the fermenters may actually show too low a temperature. In this case the must has to be warmed, a purpose most efficiently accomplished by pumping it through a heat-exchanger.

The fermentation need not continue for a long period in contact with the skins. As soon as the color has reached the desired depth or is no longer getting deeper, the wines may properly be drawn off. A visual inspection of successive samples of filtered must, taken during the fermentation, will show when color extraction is adequate. The earlier the drawing-off, the less the danger of overaerating the wine or of spoilage in the cap. As a rule, in California, the color extraction is completed sufficiently in 4 to 5 days, but the drawing-off may take place at any time between the third and fifteenth day, according to the amount of color present, the temperature of the fermentation, and the degree of astringency and depth of color desired. The Balling is usually from 4° to 6° when the color extraction has ceased, but the decrease in Balling degree cannot be used as an indication of color extraction; there is no direct relation between the Balling degree of the fermenting must and its color content.

Alternative Methods.—The peculiar chemical composition of the must and the difficult temperature conditions during fermentation have led to the introduction of numerous special methods of fermentation for making red table wines in hot countries. Some of these are of questionable value, to be used only with caution and after trial.

Among the most promising of these methods is fermentation in closed containers with the cap submerged throughout. Submerged-cap fermentations, though used for many years in this state, have not ordinarily been made in closed tanks, as is now the practice.

In a simple submerged-cap fermentation, a lattice of wood is fixed in the upper part of the open fermentation vat. The crushed grapes are introduced below and nearly up to the wooden framework. When the fermentation begins, the cap rises against the lattice but cannot push through, while the fermenting liquid rises and covers the cap. Since the cap, as was mentioned above, is the chief source of spoilage in red-wine fermentation, this method has the obvious advantage of removing the cap from contact with the air and from possible contamination. Keeping the frames clean and preventing too much pressure below them, with consequent breakage, are important details of operation.

The large free surface of liquid exposed may lead to oxidation or contamination.

Two types of closed-tank fermentations have been used recently in California. In the simplest case, the fermentation tank is an ordinary concrete vat with a concrete top, having a manhole in it for release of gas. As the tank is filled only about two-thirds, there is no possibility of the cap's rising against the top. Cooling coils are placed inside, since there will be little surface loss of heat. The chief advantage of this system is that an atmosphere of carbon dioxide is maintained over the surface so that spoilage of the cap is prevented. But punching down of the cap is difficult, and extraction of color will naturally be somewhat less. Occasionally a semipermanent framework is built inside the tank to keep the cap submerged. Tanks of this nature can be used, after the vintage season, for storing bulk wines.

The second type of closed-tank system calls for the ordinary concrete tank with the top having a raised edge. The tank is filled fuller than in the preceding case, and the cap rises to the top of the tank. There are holes in the top through which juice and gas may rise, but through which the cap cannot rise because of a wooden lattice framework which is placed just below the holes. The raised edge around the top prevents the loss of any liquid. This is essentially the old open-vat submerged-cap system in a concrete form.

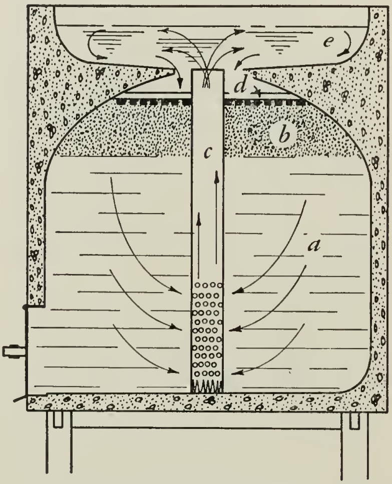

Fig. 13.—Concrete tank for *lessivage* fermentation system showing (*a*) fermenting liquid, (*b*) caps, (*c*) tube for liquid carbon dioxide mixture, (*d*) wooden rack to submerge cap, and (*e*) basin into which fermenting liquid arises and from which its carbon dioxide is partially lost.

Another method, shown in figure 13, is the Algerian *lessivage* system described by Fabre,[56] Winkler,[57] and others. In the latter, a central tube permits the rise of the gas and liquid faster than the gas can penetrate the cap. When the liquid filled with gas reaches the top, it loses its gas, and the weight of the liquid (which without the dissolved carbon dioxide is heavier than the carbon-dioxide-charged liquid rising through the

[56] Fabre, J.-Henri. La fermentation des moûts dans les pays chauds. V^eme Congrès International de la Vigne et du Vin, Lisbonne, Rapports, Tome II, Oenologie. p. 17–33. 1938.

[57] Winkler, A. J. Making red wines in Algeria. The Wine Review 3(7):14–15, 40. 1935.

cap) causes it gradually to penetrate back through the cap. When properly constructed, such tanks work automatically and provide a large circulation of the fermenting must. The submerging of the cap gives a better extraction of coloring material and prevents acetification. The objection has been that this system involves an excessive aeration of the wine, with consequent overmultiplication of the yeasts. The must is easily cooled, however, by cooling coils in the main tank or in the upper basin; and the tanks can be used throughout the year.

The other procedures suggested involve the extraction of color and tannin from the seeds and skins by the use of massive doses of sulfur dioxide,[58] by heat extraction,[59] or by storage of the grapes in carbon dioxide,[60] the resulting must being pressed and fermented in closed containers. Of these procedures, heat extraction, alone, has been used commercially in California. In the commercially used process, the grapes are heated after crushing to about 175° Fahrenheit and then pressed. The mixture of skins, seeds, and juice may be heated together, or the juice may be separated, heated alone, and then mixed with the crushed skins.

The oxidation that may occur in this procedure may be minimized or avoided by heating whole grapes. Amerine and De Mattei [61] have shown that complete color extraction may be obtained by dipping whole grapes into boiling water for about 1 minute.

Under certain conditions, the development of a procedure for readily extracting all the desired constituents from the red grape skins would be very useful if it did not adversely affect quality or prove too costly.

Drawing-off and Pressing.—Many different systems for handling the pomace and wine have been devised; the choice depends on the arrangement and facilities of the winery. In all, the wine is removed from the bottom of the vats, usually through some type of rough filter made of slats of wood.

If the color extraction has not been completed until most of the sugar has fermented, the pomace may be placed directly in a press.

If the pomace still retains sugar, distilling material may be produced by adding water to the pomace and completing the fermentation. The

[58] Barket, E. La vinerie. p. 119. Librairie Dunod, Paris, France. 1912.

[59] Bioletti, F. T. A new method of making dry red wine. California Agr. Exp. Sta. Bul. 177:1–36. 1906.

Ferré, M. Autolyse de la matière colorante dans les raisins entiers soumis à l'action de la chaleur humide—application à la vinification des vins rouges. Comptes Rendus des Séances de l'Academie d'Agriculture de France 12:370–75. 1926.

[60] Flanzy, Michel. Nouvelle methode de vinification. Revue de Viticulture 83:315–19; 325–29; 341–47. 1935.

[61] Amerine, M. A., and William De Mattei. Color in California wines. III. Methods for the extraction of color from the skins. Food Research. (In press.)

pomace of two or three tanks can be thrown together for this final fermentation. The pomace is then pressed; or the distilling material may be drawn off, and the remaining alcohol extracted from the pomace by washing or other means. Since many table-wine plants have no stills, they are forced to press the pomace as soon as the wine is drawn off, even though it may still contain some sugar.

The hydraulic basket press is preferred when the press wine is to be used in the cellar. This type of press, though somewhat more expensive to operate, extracts less of the finely divided pulp than does the continous press. The latter is the obvious choice where the press wine is used for distilling material or where refermented pomace is being pressed. In either case, if possible, the press wine should be kept separate from the free run, since the latter ages more rapidly and is much smoother.

The young wine usually contains a small amount of sugar still unfermented after drawing-off or pressing. It should therefore not be stored in a cold place, but should be kept at a fairly warm (70° Fahrenheit) temperature until its fermentation is complete. For this purpose closed tanks with a fermentation bung are desirable. Any simple bung that prevents free access of air to the wine and maintains a slight pressure of carbon dioxide in the container is satisfactory. One should always complete the fermentation at once rather than trust that it will be completed in the spring, since in many cases the wines with residual sugar may become badly contaminated and spoil during the winter. If the fermentation is especially difficult to complete, and if aeration and warming will not work, the product may have to be treated as a stuck wine and refermented by one of the procedures already mentioned (p. 37)—usually by gradually adding small amounts of the wine to an actively fermenting vat.

When the wine has completed this last fermentation, the container should be filled and loosely bunged, and as soon as the gross sediment has settled, the wine should be racked into its storage container in a cool place in the cellar.

The appearance of the young wine changes rapidly during and after fermentation. During the active process, it is murky and disturbed, but the bulkier sediment rapidly drops at the conclusion of the tumultuous fermentation. Within a month of the time of pressing, most of the remaining suspended yeast particles should settle out, leaving the wine clear. In this condition, if dry, well stored, and properly treated, it is fairly safe from spoilage.

If the wine fails to clear in this fashion, especially after an early racking, an undesirable, slow fermentation of residual sugar, or bacterial contamination, or both, is indicated. The cause of such persistent cloudiness should be determined at once. Chemical and microbiological analyses should be made.

The Balling reading is of no value in determining the dryness of the wine. At 0° on the Balling hydrometer there may still be 1 per cent or so of sugar present, because the alcohol formed has a lower specific gravity than water and tends to lower the reading. If the Balling reading is made on dealcoholized wine and is above 3.0, there is a strong suspicion that the wine contains unfermented sugar, but a chemical test (see p. 107) is the only safe method for proving the presence of excess sugar. The wine is sufficiently dry if the sugar content is below 0.2 per cent.

AGING OF RED TABLE WINES

Racking.—Red wines may be racked in contact with the air without fear of overoxidation. By December the wine should be free of the fermentable sugar and ready to be racked off the sediment. Care should be taken in racking to avoid stirring up the sediment; a good practice is to leave a generous amount of wine over the sediment. The lees (yeast, seeds, tartrates, and the like) and remaining wine from several tanks may then be pumped into a single tank, and after further settling, an additional amount of clear wine can be racked off. The remaining lees are generally used for distilling material or sold to a by-products factory for recovery of alcohol and cream of tartar. The racking may be done by siphoning by means of a rubber hose or by a pump. Or the clear wine may be drawn or pumped off through a hose connection on the side of the tank. This connection should be several inches above the upper level of the lees, as in figure 14.

If the first racking takes place in November or December, the next may be made in January or February, and a third in April before the temperature of the cellar rises.

At the first of the year, a general checkup of the wines in the cellar should be conducted. This includes an analysis of the wine (p. 106) as well as an independent, careful tasting. The wines should receive a preliminary classification; and, according to their soundness, varietal composition, and quality, a decision should be made regarding the proper future treatment. By this means the lesser-quality wines can be segregated for early clarification and sale, whereas the wines for aging can be properly stored. The midyear check is also the occasion for detecting off-flavored and diseased wines before they have a chance to contaminate other tanks or equipment during racking.

After the first year, the wines being aged will continue to deposit small amounts of sediment; and they should be racked about twice annually or less, if the wine is sensitive to oxidation.

Between rackings the containers must be regularly filled. The chief source of danger during the aging of red table wines is the development of spoilage through failure to keep containers full. This is also the chief source of spoilage in retail stores where wine is sold in bulk directly from the barrels and where large air spaces are permitted. However, when the cellar temperature rises too much and too rapidly, a consider-

Fig. 14.—Storage tanks. Usually these are placed on end. Note the racking valve in the manhole. (Photograph by courtesy of the Wine Institute.)

able expansion in volume occurs in large cooperage, and some wine may have to be removed. The contraction in volume, when the temperature drops, is greatest in large cooperage; but even small cooperage must be filled regularly. In fact, small cooperage, because of the greater ratio of surface to volume, should be watched most carefully. The lower the humidity and the warmer the air of the cellar, the more frequent the filling will have to be. During the first months they should be filled as often as every other week; during the second year, a monthly filling is usually sufficient.

Storage.—Light, fruity wines may be drunk when comparatively young. Wines of no particular character, with a light body, fall in this class; also wines whose composition makes them unsuitable for aging (such as those moderately high in volatile acid). Such wines should be brought to a stable condition and sold within a year or eighteen months. By removing them from the cellar as soon as possible, the cost of storage is reduced; and since they can never be sold for a high price, the margin of profit is increased. Such wines should be filtered, fined, and otherwise stabilized as necessary (p. 92).

The wines of heavier body and richer flavor that will be aged should be handled differently. These must be low in volatile acid, and balanced in alcohol and acid.

Any necessary blends not made at the time of crushing should be made as soon as possible after fermentation. There is no necessity for complete finishing of the wine by fining or filtering at this time, since mellowing naturally occurs during the aging. The too early removal of all tart, astringent, or rough constituents by these operations or by undue lowering of the temperature may defeat the purpose of aging. At this time, also, the temperature should be reduced, naturally or artificially, to aid in precipitation of the tartrates and in general clearing of the wine. (See p. 91).

The larger the container and the lower the temperature, the slower the rate of aging; in small containers at higher temperatures, more rapid aging is obtained. Wines aged too rapidly do not acquire the desired bouquet and may taste flat. Excessively prolonged aging is expensive and may involve undesirable changes caused by overoxidation, bacterial contamination, or excessive extraction of woody flavors from containers. In general, the smaller casks stored at low temperatures give the best results.

During the aging of red table wines, the volatile-acid content should be checked periodically. If it tends to rise unduly, small amounts of sulfur dioxide should be added; or some other method of controlling microorganisms should be followed.

PINK WINES

Only occasionally have pink wines (*rosés*) been produced in California, although they are well known and liked in France and Italy.[62] The most commonly used variety for very light-bodied, low-alcohol pink wines is the Aramon, a heavy producer that yields a pleasant, early-maturing, fruity product. The Grignolino, of a characteristic orange-red color, is widely used in Italy for such purposes. Its wines are better balanced but may be somewhat too rich in tannin unless aged for several

[62] Amerine, M. A., and A. J. Winkler. Color in California wines. IV. The production of pink wines. Food Research. (In press.)

years. Although several varieties rather widely planted in California yield light-colored wines—Mission, Mataro, Flame Tokay, Black Hamburg—their musts are all low in total acid; and usually the plantings are in the warmer districts, so that the sugar content of some of them may be too high. Except a few of the red *juice* varieties, pink wines can be made from any red wine grape by varying the time between crushing and pressing. Early-picked grapes in the best condition, if pressed immediately after crushing, yield white or very slightly tinted musts. The amount of color and the rate of extraction depend on the variety of grape, the region and season, the time of picking, the physical condition of the grapes, the temperature of the must, and other considerations. The following varieties have been particularly useful: Gamay yields a fruity, early-maturing pink wine; Pinot noir yields a fairly heavy-bodied pink wine; Zinfandel yields a tart wine of berrylike flavor; and Grenache, when grown in a cool district and picked sufficiently early, yields a soft, fruity-flavored pink wine.

Pink-colored grapes are fermented in much the same way as grapes for red wines. The pressing need not be delayed so long, since the maximum color extraction occurs rather early; but the wine maker should make constant tests as to the rate of color extraction during fermentation. If the temperature of the vats is low, often the musts may be left in contact with the skins for one night before pressing.

In Algeria large amounts of sulfur dioxide (400 parts per million) are sometimes added at the time of crushing, to check fermentation; after about 24 hours the must is separated from the skins. This juice is next allowed to settle, and the clear liquid is then drawn off and fermented by the procedures used for white wine. The wine so obtained is said to mature early and is free from stem flavors. Color standardization, however, is difficult because the sulfur dioxide discolors the must so that the proper length of time on the skins cannot be determined accurately and the resulting wine usually retains too much free sulfur dioxide.

Mixing white and red grapes is sometimes used as a method for making pink wines. The length of time on the skins depends on the variables previously listed and upon the percentage of red and white grapes. The wines made by this method are sometimes very pleasant, for they do not have the high tannin which results when light-colored varieties, such as Grignolino, are fermented for a long time on the skins.

The pink wines are seldom high in alcohol and are meant for early consumption. A total acid content of 0.70 per cent and 11 per cent or less of alcohol are common. They should have a fresh, fruity flavor.

The clarification and handling of these wines closely resembles that to be described for white wines (p. 82).

DIRECTIONS FOR MAKING DRY WHITE TABLE WINES[63]

HARVESTING AND TRANSPORTATION OF GRAPES FOR DRY WHITE WINES

Harvesting.—The directions and precautions outlined for picking grapes for red table wines largely apply also to harvesting grapes for white table wines, but the grapes should be picked even more carefully and at a slightly lower Balling degree. The white table wines should be made as light and fruity as possible, and for this result an early picking is essential. The Balling should be from 20° to 23°, and the total acid as high as possible within these limits of sugar. In general, the white wine-grape varieties have thinner and more delicate skins than the red and are hence more easily bruised in picking. The white wines are more delicate and reflect off-colors and flavors more readily than the red; hence moldy and spoiled clusters should be discarded even more rigidly. Injured berries brown rapidly, which makes the maintenance of a light color in the resulting wine more difficult. The picking boxes used should be clean and free from remnants of red wine grapes.

Transportation.—White wine grapes, which must not be carried over long distances, should always be transported to the winery in boxes and crushed promptly. From white grapes the wine maker should try to obtain a must as free from an objectionable brown oxidized color as possible. All possible precautions against breaking the skins and against subsequent oxidation must therefore be taken.

WINE-MAKING PROCEDURE FOR DRY WHITE WINES

Crushing.—White wine grapes must be pressed immediately or very soon after crushing. Crushers like those described for red wines are commonly used for white. The combination stemmer and crusher is usually satisfactory, but all the berries must be macerated. The seeds should not be crushed.

Pressing.—Occasionally the stems are left on white grapes, to facilitate handling of the mass in the press basket; but the extraction of bitter, stemmy flavors during pressing, or even by the contact of must and stems, has led most wineries to abandon this system.

The most desirable juice for making high-quality white table wines is the free-run juice that drains off the bottom of a vat containing freshly crushed grapes. If a false bottom, constructed of wooden slats (see fig. 12), is placed in the vat, a better drainage of this juice can be obtained. In some wineries the free-run juice is kept entirely separate from the press juice. If the whole mass of freshly crushed grapes is left for a

[63] General references on this subject are listed on page 134.

short period in a vat, more free-run juice will drain off, the skins will become slightly less slimy and thus easier to press, and, with some varieties, more flavor will be extracted. This period should not be extended too long, however, lest too much tannin, color, or off-flavors be extracted. There is danger, also, of extracting excessive amounts of pectins, gums, and other colloidal matters, which play an important rôle in subsequent clouding and hazing. Furthermore, the grapes may darken too rapidly in the open tank unless the sulfur dioxide content is fairly high.

Somewhat better-balanced ordinary white table wines may be produced from grapes of the warmer districts by a short fermentation on the skins; for, in such localities, the musts are too low in tannin and extract. By fermenting such white grapes on the skins for a limited time, stabler wines, higher in tannin and extract content, are produced. Musts handled in this manner, however, must be free from spoiled grapes, otherwise the wines may not be sound or palatable. If too much tannin is extracted, the amount can be reduced by a heavy fining with gelatin. This method not only gives stable wines but also increases the yield per ton of grapes. The press wine should, as usual, be kept separate, since it is harder to clarify and may be very high in tannin. This method is primarily applicable to ordinary white table wines. (See references to Dugast, p. 129 and to Fabre, p. 129.

Where the grapes are not expensive and the winery needs distilling material, the grapes are not pressed at all; but water is introduced after the free-run juice has been drawn off, and the remaining sugar is then fermented to produce distilling material.

Three types of presses are commonly used in white table wine making: basket, continuous, and rack and cloth. The basket press (fig. 15) is by far the most common. Usually it is operated by a hydraulic ram so that great pressure can be applied readily. At first the pressure should be light so that the skins will not slip between the slats of the basket. The rate of flow of the juice, first rapid, will soon decrease. The press is then opened, the pomace turned over or mixed, and the whole re-pressed to produce an additional amount of juice. The later press juices, being often bitter, high in tannin, and very cloudy, should always be kept separate.

The continuous press is not desirable for producing choice white table wine.

The highest yields of clearest must are obtained in rack-and-cloth presses, which are not widely used because of the high cost of operation involved. In this method a cloth is wrapped around thin layers of grapes, and a thin wooden rack is placed between each layer. The whole stack is placed under a hydraulic press, and a considerable pressure applied.

The total yield is fair, but the increase in quality of must obtained is small.

Settling.—To facilitate the earlier clearing of white wines, much of the coarser sediment should be eliminated before fermentation, especially with free-run juice low in tannin, which otherwise would yield a wine difficult to clear. Sometimes the must is cooled as well as sulfited in order to prevent fermentation during settling. The coarser particles,

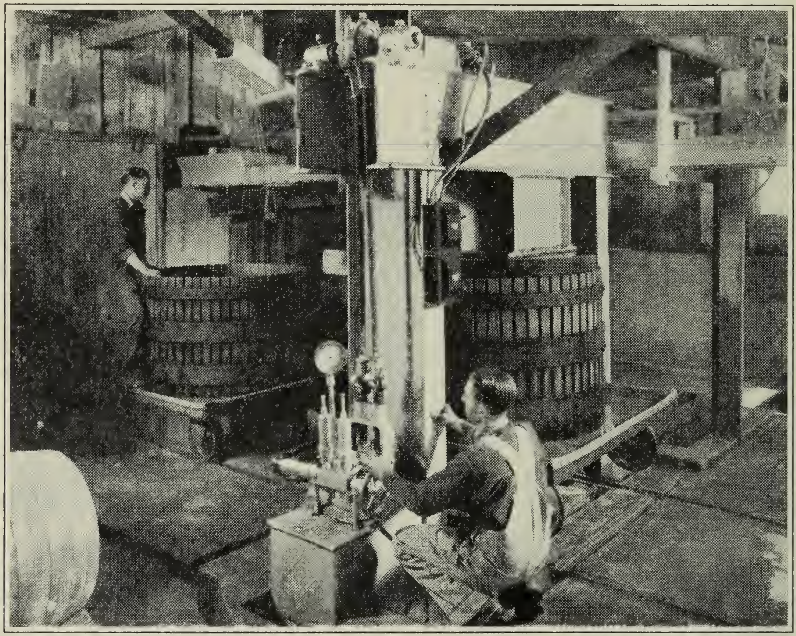

Fig. 15.—Hydraulic press and equipment. Note the pressure gauge and the extra basket. (Photograph by courtesy of the Wine Institute.)

bits of skins, seeds, wild yeasts, and the like gradually settle out; and usually within 24 hours the clear, supernatant juice can be racked off. European practices, which require a fining of the must before racking, have seldom been followed in California. Settling removes not only the fragments of grape tissue but also many of the microflora, and thus facilitates control of fermentation. The ready fermentation of warm musts hinders settling, but prompt cooling and the use of moderate amounts (60 parts per million) of sulfur dioxide will prevent this difficulty.

Occasionally the must is centrifuged to eliminate the coarser particles, but this method of clearing has not found widespread favor. Neither pasteurization of the musts (except the spoiled ones) nor filtration is ordinarily a necessary or desirable aid to settling.

Red Grapes for White Wines.—The varieties of red grapes to be used for making white wine should not yield a colored juice on pressing. Late in the season even the sound berries give a colored juice, and the rotten berries or those with broken skins always give one. The grapes should be picked early in the season and handled carefully so as not to injure the berries. A white or nearly white juice may be obtained by a gentle crushing and by drawing off only the free-run juice, the remaining fruit being used for red-wine making, or, as in the Champagne district in France, the uncrushed grapes may be pressed in special flat presses. In either case, it is necessary to cool and sulfite (75 parts per million) the free-run juice and allow the skins, seeds, and other waste, which would add color to the wine during the fermentation, to settle out. Some of the pink color, which is extracted by crushing or pressing, will disappear during fermentation and racking. White wines from red grapes have a heavier body than wines from comparable white grapes.

Correction of Deficiencies.—White musts lacking acid can be conveniently balanced before the addition of pure yeast. The amount of acid added will depend upon the original acidity of the must and upon the type of wine (p. 35). The addition of acid before fermentation, although more expensive owing to the amount lost in the lees, gives smoother wines, which usually have cleaner fermentations. The proper amount of acid should be dissolved in a small volume and added to the must, which should then be thoroughly mixed. California white musts should usually be brought to at least 0.7 per cent acid before fermentation, preferably with tartaric acid. The addition of tannin to white musts is common in some European countries and may be advantageous under some conditions here. (See p. 37 and 79.)

Fermentation.—The inoculation of the must with pure yeasts should take place immediately after racking off the sediment in the settling tanks, in which the must has been sulfited. For white wines, a yeast which gives a rapidly settling, compact sediment is especially desirable.

The fermentation of white wines should therefore take place in closed containers, about two-thirds full. Some wineries favor filling the fermentation container more than the customary two-thirds so that the yeasts and other matter that rise to the surface during the violent fermentation will flow out. Ordinarily, fermentation bungs may be used to prevent the free access of air to the fermenting must; but in the first stages, when the fermentation may be rather violent, there is often sufficient surface foam to plug the bungs. Consequently a simple, curved metal tube is sometimes fitted into the bung hole to conduct the excess foam into a tub or a drain. Bungs are not necessary for large closed fermenters, from which the volume of gas liberated is very great.

White table wines fermented in open containers not only are subject to undue oxidation, especially in the later stages of fermentation, but may become contaminated.

The fermentation should be conducted at a temperature lower than for red wines. The color, flavor, and aroma of dry white wines are injured at 85° Fahrenheit or above. The most desirable temperature is apparently about 75°, although many quality-wine producers prefer one somewhat less. At 70° and 75°, the rate of fermentation is lower; but the fermentation is cleaner, and the temperature is not liable to get out of control during its most active stages. To maintain such temperatures as these, some wineries use small cooperage, artificial means of cooling, and the like. Refrigeration during fermentation is usually necessary and yields sound wines of improved quality (p. 48).

Because white wines are fermented at lower temperatures, out of contact with the air, the period of fermentation is prolonged. If, however, the wines are not finished in 4 to 6 weeks, they must be aerated to invigorate the yeast. Towards the latter part of the season, as the temperatures drop, it may become difficult to finish the fermentation of white wines without one or two aerations or even warming of the musts. But the aeration of white musts and wines should not be excessive if darkening of color and spoilage are to be avoided.

After the active period of fermentation, the tanks should be filled and kept full. Since the volume decreases rapidly at this period, the casks may need filling once a week.

Other methods of fermenting white wine grapes, such as the Semichon process of controlling fermentation by maintaining the alcohol content in the fermenting must above 4 per cent, have not been found successful under California conditions.

AGING OF DRY WHITE TABLE WINES

Racking.—White wines are best when removed from the lees promptly after fermentation is over. Otherwise, in warm weather, various unpleasant odors and flavors, caused by decomposition of yeasts and the like, may be added to the wine. At this period, also, conditions favoring the formation of hydrogen sulfide are set up in the lees. Indeed, there is no objection to racking white wines off the sediment as soon as the fermentation is complete; and frequently, if only a trace of sugar remains, the aeration during removal of the wine from the lees will be beneficial in finishing the fermentation as well as in aiding the removal of undesirable metals by oxidation. Early racking and cooling are especially important in California to maintain a high total acidity. The initial racking should always take place before the first of the year.

The number of additional rackings should be based on the amount of sediment being deposited and upon the clarity of the wine. Aeration of the young white wine is seldom desirable. Often where very delicately colored and flavored wines are produced abroad, the rackings are carried on under a slight pressure of carbon dioxide in order to prevent access of the air to the wine. This procedure and, in general, the handling of white wines under a protective blanket of carbon dioxide, would go far toward preventing the overoxidation so common in California.

Sulfur dioxide is especially useful in handling white table wines. Its rational use protects them against a too dark color, an oxidized, sherry-like flavor and aroma, and bacterial disease. It is also valuable in removing small amounts of hydrogen sulfide, which are occasionally found. Since the sulfur dioxide is constantly being dissipated by oxidation, volatilization, and the like, it must be renewed at regular intervals. Naturally, the cooler the cellar, the cleaner, drier, and more acid the wine; and the larger the container, the less will be the danger of contamination or oxidation and the smaller the amounts of sulfur dioxide necessary. But in warm cellars (or in the summer), for low-acid, slightly-sweet wines in small cooperage, larger amounts must be used. Under favorable conditions less than 50 parts per million of sulfur dioxide will suffice. Under adverse conditions 75 to 100 parts per million may be necessary.

Clarification.—Properly made and balanced white table wines should not be cloudy in the spring after the vintage. If any cloudiness persists, the wine should be examined for bacterial contamination.

The main problem in white wines is to secure, as early as possible, wines that will stay brilliantly clear in the bottle. Certain high-acid. low-pH, light wines of Europe reach this condition within a year without undue treatment. Unfortunately, the ordinary white table wines of California seldom show any such natural tendency to early clarification. The cause is probably their high content of various colloidal matters, their high pH values, and the prevailing high-temperature conditions of the cellars. Such wines require more strenuous inducements to clearing.

White wines should be placed at a low temperature (below 32° Fahrenheit) after the first or second racking, to facilitate the precipitation of excess tartrates and of other slightly soluble substances. If cooled in a separate room they are easily racked thereafter. At this time, care must be taken not to aerate the wine too much lest it take up excessive oxygen. It should not be kept at the low temperature any longer than is necessary to secure the desired precipitation. Usually the wine is rough-filtered off the precipitate. The filtration should be done at a low temperature to avoid redissolving some of the precipitated materials.

Fining usually takes place in the spring. For white table wines it should be completed before the warm weather. The usual tests (p. 93) should be conducted on each container, and the proper agent and amounts added. The fining agent should not be left in contact with the wine too long as decomposition of the collodial material in the precipitate may impart an undesirable flavor. The usual procedure is to filter the wine off the sediment—a safer procedure than simply pumping it away, although young white table wines should not be filtered too close.

If the clarification has been successful, the wine should be nearly brilliant without undue darkening of the color. Early clarification of all wines, regardless of their quality and the length of time that they are to spend in wood, results in less danger of bacterial spoilage. Excess manipulation—fining, filtration, and the like—is detrimental to quality.

Storage.—White wines bottled young (one to two years old) are lighter in color, higher in fermentation aroma, less in bouquet and barrel flavor, and fresher and fruitier in taste, particularly when protected against oxidation. In some, the presence of small quantities of carbon dioxide improves the flavor and appeal. Judging from Laborde's tests with the white wines of Bordeaux, wines bottled at one year of age were always of better quality than wines left in the cask for more than one year.[64]

As a rule, white table wines in California are kept in casks from one to three years for additional aging and clarification. They are usually placed in the coolest part of the cellar. It is questionable whether keeping them in a cask after three years is advisable; often, California wines have too much oak flavor and become excessively dark when kept in small containers in the usual warm cellars for over two years.

DIRECTIONS FOR MAKING NATURAL SWEET TABLE WINES[65]

HARVESTING AND TRANSPORTATION OF GRAPES FOR NATURAL SWEET WINES

The process of making natural sweet wines in California differs somewhat from that in France and Germany. In the latter countries, the growth of a fungus, *Botrytis cinerea,* on the surface of the grapes removes considerable water, and thus increases the sugar concentration. Increased contents of glycerin and oxidase and decreased nitrogen and total acid also result. In the absence of the *Botrytis,* those who wish to

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[64] Ribéreau-Gayon, M. J. Vinification des vins à appellation d'origine en France. p. 211–21. Congrès International du Vin. Librairie Universitaire J. Gamber, Paris, 1937.

[65] General references on this subject are listed on page 134.

make natural sweet wines are largely restricted to picking the grapes at a proper stage of maturity. Since the California climate, though preventing growth of this mold, makes possible a very high sugar content, and since in most years the picking can come fairly late, it is not difficult to secure properly matured grapes for making natural sweet wines. The Balling for the moderately sweet types should be 24° to 26°. The sweeter Chateau types should, if possible, be made from grapes with even higher Balling readings. The chief precaution necessary is to prevent the grapes from unduly drying as a result of staying on the vines too long, for wines made from such grapes have undesirable flavors and are too dark in color. In hot years excessive drying may occur very quickly in certain varieties, but the risk must be taken in order to secure a sufficiently sweet must. Musts high in total acid should not be used for natural sweet wines even if their sugar content is satisfactory, since they do not make a natural sweet wine of satisfactory balance. In addition, most varieties reflect the crop and soil conditions at their maturity. The vineyards with the poorer soils and the least crop will ordinarily give grapes with the highest sugar content and are more suited to making the sweeter types of the natural sweet wines. Sunburning, however, occurs more easily where the foliage is scanty.

It might be desirable for the pickers to separate two grades of grapes in harvesting: riper bunches from the greener bunches, and the fruit from the vines with the small crop, which are sweeter, from the less sweet fruit of the heavily laden vines. By such sorting, with some varieties one can obtain grapes with a Balling as high as 28°, well suited for making the sweeter types.

The precautions outlined for the picking and transportation of the grapes for red and white table wines apply also to those intended for making natural sweet wines.

WINE-MAKING PROCEDURE FOR NATURAL SWEET WINES

Crushing and Pressing.—The grapes are crushed and stemmed, the free-run juice is ordinarily separated, and the pomace pressed in basket presses as for white table wines. The grapes for natural sweet wines are rarely fermented on the skins for even a short time. The crushing of semidried grapes for natural sweet wines is much more difficult than that of the plump, juicy grapes for dry table wines. Rollers, if used, must be set closer together, an arrangement that increases the danger of breaking the seeds; or, if a rotating cylinder is used, the propellers must be operated more rapidly. Rollers are almost always necessary for these types of grapes. The first pressing should be very slow. Thereafter, the pomace should be well stirred. In France and Algeria special equipment is often used to disintegrate the pomace of the first press before making a second pressing; these are usually rotating cylinders leading from one press to another. Greater yields are said to be obtained in this manner. The pomace being rather sweet, is usually saved for producing distilling material.

Settling.—The very sweet, sometimes viscous, musts used for these types of wines are often high in colloidal matter and frequently yield wines that are especially difficult to clarify. If at all possible, then, these musts should receive a preliminary settling before fermentation. The musts should be cool or cooled immediately after pressing. A generous amount of sulfur dioxide should also be applied (100–150 parts per million). If no fermentation starts, the musts should settle fairly clear in from 12 to 24 hours; and the supernatant liquid can then be racked off the sediment.

Control of Fermentation.—Musts with the highest sugar content should be used for the sweeter types, those with the lower sugar content for the drier types. Those with Balling below 24° should not be used for making any natural sweet wine, since they will be too low in alcohol and in extract when finished. A rough calculation will show how much of the sugar present is necessary to produce a 12–14 per cent alcohol wine; and the balance of the sugar will, if the fermentation is properly conducted, remain in the wine. As some sugar will be lost during the year or two which the wine must spend in wood, the fermentation should be stopped somewhat above the desired percentage of sugar. The chief problem in making natural sweet wines is to halt fermentation at the proper stage. This involves complete control of the rate of fermentation throughout the vinification. Because, naturally, this can be more satisfactorily achieved in small than in large cooperage, most natural sweet wines are made in tanks of less than 1,000-gallon capacity. If there has been no preliminary settling and if no sulfur dioxide has been previously added, it should be added at this time in amounts of about 50–150 parts per million—according to the quality of the grapes and the temperature conditions (p. 41). In addition, the must should be cooled to below 70° Fahrenheit. A pure yeast is added a few hours after the sulfur dioxide. The fermentation should be slow. If it tends to become too rapid, the must should be cooled, and possibly more sulfur dioxide added. The practice of letting the temperature rise and having the fermentation stick with residual sugar in the wine is very undesirable.

As the sugar content of the must gradually drops to the desired level, the rate of fermentation should be reduced. The Balling reading is not an accurate measure of the sugar concentration at this time, because varying amounts of alcohol are present. For an accurate picture of the pertinent components of the wine, the alcohol and extract should be measured (p. 106, 107). If fermentation has not been too rapid, the yeasts will be mainly in the lees and one can slow it down considerably by racking the must off the yeast one or more times during the process. If the racking is properly done, only a few yeast cells will be transferred; and they will have to multiply before further appreciable alcoholic fermentation can take place. The fermentation is slowed down not only by this reduction in yeast population, but also because the nitrogen and phosphorus content of the must is gradually reduced so that the yeasts multiply much less rapidly. If such a system is to be successful, the fermentation must not be violent enough to stir up the lees continuously. To achieve this purpose, a cool fermentation is obviously essential.

One may stop the fermentation by adding massive doses of sulfur dioxide and racking. The objection is that such wines contain excessive amounts of sulfur dioxide and are often unpalatable.

Another method of stopping the fermentation is filtration. Various types of rough filters will remove large amounts of yeast. By an appropriate setup of filters, one can practically sterilize an actively fermenting wine. Where large volumes are to be filtered, however, this method is hardly practicable, since it would require many changes of the filter pads and might remove substances that contribute to the body of the wine.

The most rational procedure for making natural sweet wines is to control the rate, extent, and character of fermentation by cooling and by frequent careful rackings followed by the addition of small doses of sulfur dioxide. The fermentation is thus controlled by a gradual depletion of nutrients required for yeast growth and by the use of sulfur dioxide under optimum conditions (smaller numbers of microörganisms and lower temperatures). Such practices also result in a higher accumulation of desirable by-products of fermentation, particularly of glycerin.

Methods of making natural sweet wines by adding grape concentrate and the like to dry white table wines do not yield a quality product. Addition of brandy is also undesirable. Although musts preserved (mutéd) with a high concentration of sulfur dioxide are sometimes added to dry white table wines, this method also is not considered favorable to the production of the highest-quality, natural sweet wines. The clarification of wines prepared by such additions is also usually difficult.

AGING OF NATURAL SWEET WINES

Use of Sulfur Dioxide.—During the first winter, three or four seasonal rackings should be made in order to eliminate yeasts and other microörganisms. Since considerable sulfur dioxide is lost during racking, it must be renewed after each. The amounts added must be based upon an actual analysis of the wine and upon its condition.[66] The use of unnecessarily high amounts of sulfur dioxide is to be avoided. Proper fermentation to deplete the nutrient material and storage at low temperatures will reduce the amount needed.

From three to six rackings the first year are not unusual. The sooner the wine can be brought to stability and brilliancy after fermentation, the less is the danger of bacterial spoilage contamination, and the less is the loss of sugar by a secondary fermentation. As Casale[67] notes, wines low in acidity and rich in sugar must have a higher sulfur dioxide content for preservation. During aging, the total amount of sulfur dioxide required in the wine gradually decreases. When the wine is properly matured, the sulfur dioxide content will not be objectionable in the finished wine.

Storage.—Natural sweet wines, like white table wines, are fined before the end of the first year and are bottled as soon as matured. They should be stabilized to fairly cold temperatures, since they are commonly cooled before serving. Though the aging period for natural sweet wines may last from two to four years, the tendency is to free them of sediment as early as possible and to bottle them fairly young. Before bottling, one should very carefully determine the free and total sulfur dioxide. The wines should not exceed the legal limits for either and, in addition, must not smell objectionably. The color of a mature natural sweet wine must not be bleached by high sulfur dioxide, but also should not be darkened by overoxidation. The preferred color is a moderate gold, but with no traces of amber. It is especially useful, with natural sweet wines, to make sample bottlings to see whether the wine will remain stable in the bottle.

These wines, because of their high sulfur dioxide content, must be kept from all contact with metals throughout their storage. Pasteurization in copper-containing equipment must be particularly avoided. They should not be kept in concrete tanks.

MISCELLANEOUS TYPES

Several types of natural sweet table wines other than those previously described are produced in California. A pink-colored natural sweet wine of Muscat flavor made from Aleatico grapes is among the most promising. Slightly sweet white wines with a pleasing Muscat flavor are

[66] The handling of natural sweet wines should always be done in connection with an analysis of their free and total sulfur dioxide content.

[67] Casale, Luigi. L'acide sulfureux en vinification. V^{ème} Congrès International de la Vigne et du Vin, Lisbonne, Rapports, Tome II, Oenologie. p. 86–94. 1938.

also coming into production. Wines of these types are best when they have a fresh, fairly tart flavor. These types are produced in a similiar fashion to the other natural sweet wines. Fermentation at low temperatures is especially desirable.

DEVELOPMENT OF WINE[68]

AFTER FERMENTATION

When the wine in the fermenting vat is drawn off, it nearly always contains a small amount of fermentable sugar. In the making of sound dry wines, the fermentation must not cease until all the sugar has disappeared and prompt and complete attenuation has been obtained. Before the wine is ready for consumption, it must be rendered clear. While clearing, it also undergoes certain favorable changes in color, odor, and taste that distinguish an old from a young wine. To complete the fermentation, the new wine is placed in closed storage tanks with fermentation bungs and is maintained at a suitable temperature (70° to 85° Fahrenheit). If the wine still tastes sweet a week after being placed in storage casks, it should be well aerated by pumping over. In cold weather it may have to be warmed to 75° to 80°.

In Storage.—After fermentation ceases, the yeast and suspended particles of skins and pulp settle rapidly and form a sediment known as the first or crude lees. When the fermentation is complete, the new wine is drawn off (racked) from the lees, to aid in clearing and to avoid extraction of undesirable flavors from the old yeast. Prompt removal of the yeast cells also improves the keeping quality of the wine by preventing reabsorption of nutrient constituents present in the yeast. The cleared wine is stored in completely filled and sealed tanks, which are kept full during storage. Racking is repeated more or less regularly to aid in clearing. During racking, the wine loses the carbon dioxide with which it is charged and absorbs oxygen necessary to aging. No oxidation, and consequently little aging, will occur as long as the wine is charged with carbon dioxide.

EFFECT OF AGING

Aging is a complex process of oxidation and esterification, resulting in the formation of desirable aroma and bouquet and in loss of the raw flavor of new wine. A separation and deposition of excess cream of tartar occurs during storage.

Sound wine, under suitable aging conditons, becomes mellow and smooth, loses its early harshness, and forms a bouquet more complex and delicate than the simple fruity fragrance of a new wine. A decrease

[68] General references on this subject are listed on page 135.

in acidity occurs, caused chiefly by the precipitation of cream of tartar but partly also by the combination of the acids with the various alcohols, especially with ethyl alcohol. An increase occurs in the amount of alcohol in combination with acids; various aldehydes, acetals, and other oxygenated bodies are formed. A decrease in the tannin content occurs, accompanied by formation of a deposit containing oxidized tannin and coloring matter. Red wines decrease in color and gradually become tawny or brown, while white wines acquire an amber hue with age.

Oxidation.—The improvement of the wine in storage vats or casks is attributed chiefly to oxidation; the attainment of the final quality after bottling, may be traced largely to the formation of esters.

The wine should be oxidized to the proper degree by aging in the cask before bottling. If the wine is bottled too young, it may spoil or mature too slowly; if bottled too old, it will lack fruitiness, be vapid and off-colored. The best wines result from a proper balance of cask- and bottle-aging. It is desirable to bottle choice wines early and allow them to mature more slowly in the bottle.

After most of the suspended material has settled out and the surplus carbon dioxide gas has been removed, the wine is slowly oxidized by the oxygen absorbed through the pores of the cask, also by contact with the air during loss by evaporation and during racking. The oxygen is fixed by the wine shortly after absorption, apparently by the reduced metallic ions present.[69] These, in turn, upon oxidation, act upon other constituents, so that eventually the oxygen absorbed is transferred to certain oxidizable principles, notably the tannins and coloring matter. The action of oxygen is not completed at once; the preliminary effects are often undesirable but transitory; and the primary oxidized substances continue their action. Oxygenated bodies are formed from the alcohol and tannins, and the result is a deposit of insoluble matter. The first effect of air or oxygen is to make the wine flat, unpleasant, and sometimes bitter; but if protected from too much air and stored for some time, the wine recovers and improves.

When oxygen is introduced into a wine either at too rapid a rate or in excessive amounts, the metallic ions can no longer serve as oxygen carriers, and direct oxidation results. This causes the wine to take on a decidedly rancio flavor, characterized by an accumulation of free acetaldehyde.

The esters found in wine are of two main types: the volatile odoriferous esters formed from the volatile acids (chiefly acetic); and those

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[69] Ribereáu-Gayon, J. Contribution à l'étude des oxydations et réductions dans les vins. Application à l'étude du vieillissement et des casses. 2nd ed. 214 p. Librairie Delmas, Bordeaux, France. 1933.

formed from the fixed acids such as tartaric and malic. The bouquet is due in part to the harmonious blending of the large number of esters, produced from the various alcohols and acids, with other aromatic constituents. Esterification, other than that caused by the agency of enzymes secreted by microörganisms, is ordinarily slow.

The rate of maturing varies with the kind of wine, the extent of aeration, the type of storage container, and the temperature of storage. The higher the content of tannin, residual sulfur dioxide, and other reducing substances, the slower will be the aging, and the longer must be the period of storage for aging. The more intense the aeration, the more rapid the aging. Small casks and frequent rackings increase the aeration and, therefore, the rapidity of aging. Large casks and low temperatures retard these changes. If the process is too rapid, the wine does not acquire its finest qualities but becomes vapid; if it is too slow, the aging is unduly prolonged, and the wine is longer exposed to the possibility of injurious changes or contamination. In general, the best results in quality are obtained by the use of small casks and low temperatures. Where such temperatures are unavailable, larger casks must be used. Oak casks are particularly desirable, not only because of their porosity but also because oak extractives improve the flavor of wines, particularly red table wines.

Temperature.—Temperature markedly affects aging. The lower the temperature, the more speedily do the yeasts and other microörganisms become inactive and settle out, and the more rapidly and completely will excess cream of tartar be precipitated. A wine should therefore be kept cold for several weeks after fermentation, in order to throw out of solution the excess salts and to deposit the microörganisms. Many of the gums and proteins, on the other hand, are eliminated more rapidly at higher temperatures; and at such temperatures, aging is more rapid. When separated from all the sediments, however, table wines develop best at an even temperature between 50° and 60° Fahrenheit.

Chilling wine close to the freezing point is an effective means of quickly eliminating cream of tartar from new wines and may be used in preparing ordinary table wines. According to data obtained by Marsh and Joslyn[70] on the conditions affecting the rate of cream-of-tartar deposition, a mere cooling of the wine to a temperature just above freezing, as in some current installations in California wineries, is not sufficient to separate appreciable amounts of cream of tartar. To remove any considerable portion, the wine must be stored at the cool temperature for a period that depends upon its nature and upon the temperature of

[70] Marsh, G. L., and M. A. Joslyn. Precipitation rate of cream of tartar from wine. Industrial and Engineering Chemistry 27:1252–56. 1935.

storage. Thus for dry white wine, storage for 3 days at 50° Fahrenheit, between 1 and 3 days at 40° and 32°, and less than 1 day at 25°, reduced the cream-of-tartar content to that of the sample stored at room temperature for 225 days. The rate of precipitation of cream of tartar was fairly rapid in the initial period and then decreased, becoming very slow after 12 days at practically all temperatures used, because of decrease in the extent of supersaturation. The decrease in rate of separation, however, appeared to be more rapid than would be accounted for by decrease in cream-of-tartar concentration. The rate of precipitation increased with decrease in temperature; thus 30 per cent of the cream of tartar present was removed after storage for 5 days at 50°, about 3 days at 32° and 40°, and but 2 days at 25°.

Period of Aging.—Since so many factors intervene in determining the length of time necessary for obtaining the optimum quality by aging, the period of aging alone is not a sufficient sign of maturation. Thus, wines stored in large containers may be as young after several years' storage as they were initially, whereas wines in small casks in warm cellars mature so fast that they become overaged in a year or so. Wines improve with age only up to a certain extent, and beyond this point they decrease in quality.

FINING

Although a sound wine often becomes brilliantly clear by natural settling, cloudiness may persist. In that case, clarification can be aided best by fining, filtration, refrigeration, centrifuging, or heating. Fining hastens aging, defecation, and bottle maturity. Even the best wines are nearly always fined at least once immediately before being bottled. In fining, the small particles of suspended material are induced to coalesce and form larger particles, which settle out by gravity, carrying other suspended matter down with them.

Agents.—The commonly used fining agents are gelatin, isinglass, casein, albumen, and bentonite. These, either by combining chemically with the colloids or by neutralizing the electrical charge of these particles, cause coagulation and settling. Gelatin and similar fining agents that combine with the tannin decrease the tannin content of wine and cause noticeable decrease of color. In certain light wines where loss of color is not desirable, egg albumen or isinglass should be substituted for casein or gelatin. Prior addition of tannin also will prevent the bleaching of color by casein or gelatin and facilitates rate of sedimentation. The fining agents dissolved in water are thoroughly mixed with the wine, which is then stored till the suspended matter settles out. It can then be racked and, if necessary, filtered.

The amount and type of fining agents to use will depend upon the nature of the suspended matter and upon the type of wine. The usual amount of the respective fining agents added per 100 gallons is as follows: about ½ to 1 pound of bentonite; ½ to 1 ounce of gelatin; 4 to 8 whites of fresh eggs or their equivalent in egg albumen (1 ounce of dried egg albumen); or 4 ounces of specially prepared soluble casein. The best fining agent of animal origin is isinglass. This is added in preparation for bottling at the rate of ¼ to ½ ounce per 100 gallons.

The isinglass may be dissolved in water or wine, preferably cold, by soaking it overnight and then grinding or rubbing it on a fine screen. A brilliantly clear wine results if the clarification is successful; but as the isinglass sediment is light and fluffy, care should be taken to avoid disturbing it in racking. In using this clarifying agent, add it slowly to the wine, with vigorous stirring or pumping over to mix it in thoroughly. If necessary, tannin approximately equal in weight to the isinglass may be added several days before the isinglass.

In fining with gelatin, only the purest edible grades, free from objectionable odor or taste, should be used. It should be dissolved in warm water to form a solution of about 2 ounces per gallon. As with isinglass, tannin about equal in amount to the gelatin, depending on the wine, should be added to the wine several days before the gelatin. The gelatin is added slowly with stirring or pumping over; the wine is then allowed to settle and is racked from the sediment after several days.

Specially prepared soluble odorless and tasteless casein salts may be used as directed for gelatin.

Clarification by fining with bentonite[71] (a special montmorillonite clay with tremendous swelling and other colloidal properties, mined in a limited region of Wyoming) has largely supplanted all other methods in California for bulk wines, because of the ease with which it is used. Some, however, believe that bentonite adversely affects the flavor of fine wines and therefore use gelatin or isinglass. Bentonite is now available in a powder, which can be readily made up into a smooth suspension and added directly to wine. Accurate control tests need not be carried out, since an excess of added fining agent causes no clouding. Settling is complete and rapid; the sediment is usually heavy and compact. Increasing the temperature to 120° Fahrenheit has been shown to speed up materially the coagulation and settling of bentonite.

One should usually conduct small-scale fining tests in the laboratory before attempting to clarify the cask or tank of wine in the winery, for the purpose of testing the efficiency of the fining agent and determining its effect on the wine and the quantity necessary to clarify.

[71] Saywell, L. G. The clarification of wine. California Wine Review 2(5):16–17. 1934. *Also in:* Industrial and Engineering Chemistry 26:981–82. 1934.

FILTRATION

In the clarification of wine, filtration is usually a necessary supplement to settling, racking, and fining. Very cloudy wines may be filtered to clear them rapidly; bulk filtration of this type is used also in preparing ordinary wine for market. All wines to be bottled are given a finishing or polishing filtration just before bottling. The type of filter used depends not only on the quality of wine but also on its condition. Close

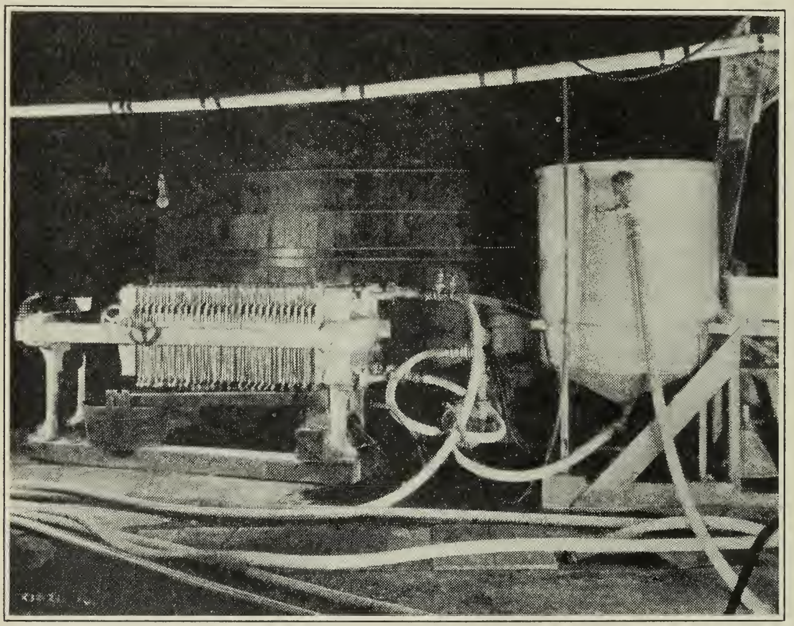

Fig. 16.—Bulk-type filter press. The tank at the right is for mixing of wine and filter aid. Note the large redwood tank in the background. (Photograph by courtesy of the Wine Institute.)

filtration is used rather extensively abroad for sterilizing the wines by removing all microörganisms. Particularly in a finishing filtration, the wine must be protected from excessive aeration and from contamination with metallic impurities from the filter lines and the filter medium. The introduction of iron and calcium salts from poorly manufactured filter pads, filter aid, or filter mass may cause cloudiness.

Bulk Filtration.—For bulk filtration, pulp filters and filter presses are commonly used (fig. 16). In both these filters, the wine is forced through the filter media by means of a suitable pump, preferably a centrifugal one.

The pulp filters consist essentially of several thick disks of cotton pulp, separated by corrosion-resistant metal screens, placed in a metal cylinder. The wine is admitted to the cylinder in such a way that each layer of pulp will act as an independent filter and so that a large aggregate filtering surface will be obtained. The filter pulp, after use, must be carefully washed, sterilized, and reformed into disks to be used again. Because of the danger of infection from improperly washed pulp and the high cost of operation, this type of filter is seldom used.

Filter presses, which should be constructed of corrosion-resistant metals throughout, are more popular. These accomplish filtration by forcing the wine under pressure through canvas sheets, precoated with diatomaceous earth and held between corrosion-resistant metal plates. To minimize the sliming and clogging effect of the soft and amorphous particles, which tend to pack together and clog the filter pores, the wine is mixed with a filter aid. For best results, the filter aid must be uniformly mixed with the wine and held in suspension by constant agitation during filtration. The amount of filter aid necessary varies with its character and with the type of wine. An excess is to be strictly avoided, and the filtration should be so conducted that all particles of the aid are removed; otherwise, the wine may take on undesirable flavors.

Leaf-type filters, consisting of hollow perforated metal screens in a suitable housing, are used also. In this type of filter, the wine is forced through filter aid deposited as a precoat on the outer surface and is pumped out of the center space.

Polishing or Finishing Filtration.—Asbestos- or fiber-pad filters and porous porcelain- or carbon-candle filters are used in final filtration just before bottling. The pads are held between corrosion-resistant metal frames in such a way that each pad acts as an individual filter. They are available in various porosities; but the pads are costly and, after use, must be discarded. To reduce contamination with acid-soluble iron and calcium salts, the pads may be washed with a 1 per cent solution of tartaric acid before use. The candle filter consists of several large unglazed porcelain or porous carbon tubes closed at one end and housed in a closed metal chamber. The fine pores of the candle act as a filter. The wine to be filtered in either the pad or the candle filter must be nearly clear. The clarity of the filtered wine should be checked periodically during filtration, visually or preferably by some physical method.

Sterilization Filtration.—When the pore size of the filter medium is small enough and the filtration is carefully conducted at not too high a pressure, all microörganisms may be removed from the wine. If such closely filtered wine is filled under aseptic conditions into sterile bottles and is closed with sterile corks, it will not be subject to bacterial spoilage. Scrupulous care must be taken, however, to avoid reinfection at bottling;

and all the operations must be conducted in a clean room in the most sanitary way. The bottles may be sterilized by thorough washing and then rinsed with a solution of sulfurous acid and sterile water before use. Only corks of high quality, properly sterilized, will serve. Sterilization filtration is at best difficult; may be dangerous when improperly used, because of reinfection; and is probably impracticable in the average large wineries.

CENTRIFUGING

Although rarely used in Cailfornia wineries, centrifuging offers some possibilities for the clarifications of musts and wines. The centrifuge, however, may unduly aerate dry wines and is mainly used for musts, and dessert or appetizer wines. It should be constructed of corrosion-resistant metal and after use be thoroughly drained and washed. In operation, the centrifuge will remove both large and small particles according to the speed at which it is turning. When improperly operated, there may be a slight loss in alcohol from the wine.

PASTEURIZATION

Wines are pasteurized primarily to destroy injurious microörganisms capable of developing in them; but sound wines, particularly when they are to be aged, need not be pasteurized. Pasteurization is widely used to check the progress of bacterial diseases, although sound wines are sometimes pasteurized to insure their keeping under unfavorable conditions. The process does not, however, render the wine immune; and the sterilized product must be run into clean sterilized casks and protected from reinfection. Pasteurization has been used along with fining to promote the more complete separation of suspended matter; but cloudy wine should be cleared before pasteurization, in order to avoid injuring its flavor. If the wine is heated to a suitable temperature and held there for the proper period, the organisms that can develop will be destroyed. The higher the temperature, the shorter the necessary time of heating. The amount of heating needed will depend upon the extent and type of infection and upon the composition of the wine. The smaller the number of microörganisms and the higher the acid and alcohol content, the less the heating required. Pasteurization when necessary should be accomplished with minimum injury to the flavor of the wine. For this reason a continuous pasteurizer in which the wine is heated rapidly to the desired temperature, held there for a short period, and cooled rapidly, is better than a discontinuous pasteurizer. Heating to 180° Fahrenheit for 1 minute is usually sufficient to kill most injurious organisms found in California wine.

Pasteurization, as a means of preserving wines particularly susceptible to bacterial diseases or to refermentation by yeasts, may be accomplished in several ways. In one, the wines are filled cold into the bottles, sealed with a special closure, heated lying on their sides in water at 140° Fahrenheit for some 30 minutes, and cooled. In another, the wine is flash-pasteurized in a suitable pasteurizer; cooled to a bottling temperature of 140°; and filled at that temperature into steamed bottles, which are then closed, turned over to sterilize the closure, and cooled. Since pasteurization will usually precipitate some colloidal material, the wine should be bulk-pasteurized, cooled, and filtered before bottling.

The pasteurizers should be constructed of corrosion-resistant metal. Copper and brass are particularly undesirable for use in contact with hot sulfited wines. The pasteurization of such wines in copper-bearing equipment almost always results in sufficient metal pickup to result in copper casse. (See p. 126.)

CHAMPAGNE AND OTHER SPARKLING TYPES OF WINE[72]

DEFINITION

Wines that retain a permanent excess of carbon dioxide are commonly known as "sparkling." The various types are distinguished from each other by their method of manufacture. The largest volume of sparkling wine is a white variety, produced by a secondary fermentation in a closed container, called "champagne"[73] in this country, if produced in a closed container of 1-gallon capacity or less. Wines produced by a secondary fermentation in large-sized, closed containers (Charmat and other processes) are called "champagne type" or "champagne-style" or "American (or California, etc.) champagne-bulk process" if they have the taste, aroma, and characteristics generally attributed to champagne. Other white wines, artificially charged with carbon dioxide and known to the trade as carbonated Moselle, carbonated hock, or the like, may not at present be called "sparkling wine." Sparkling Burgundy is a red wine produced by a secondary fermentation in a closed container. Various pink wines are also made mainly by natural fermentation in closed containers.

Up to bottling, the treatment of wine intended for bottle fermentation, for secondary bulk fermentation, and for carbonation is largely the same. For all purposes, a low-volatile, tart, brilliant, and impeccably clean wine is required; somewhat older and more alcoholic wines may be used for carbonation than would be suitable for bottle fermentation.

[72] General references on this subject are listed on pages 135 and 136.

[73] This wine is *Sekt* or *Schaumwein* in Germany, *spumante* in Italy, *vin mousseaux* when produced outside the Marne district in France, and *champagne* when made in the delimited Marne area.

THE STILL-WINE BASE

Varieties.—The general details given for the picking, crushing, pressing, and fermentation of white wines are applicable to the making of a satisfactory still wine for use in producing white sparkling wines, particular care being paid to selecting grapes of proper maturity and type and to obtain a clean, cool fermentation.

The favorite varieties for these wines are Chardonnay, Pinot blanc and Pinot noir, pressed before fermentation. The Pinot flavor seems especially suitable to wine of this class. Under California conditions, these varieties ripen before the usual wine-grape varieties and, if they are to be used for making sparkling wines, must be picked very early. Even so they are sometimes too low in acid, and their musts may have to be ameliorated by addition of acid or blending with high-acid wines.

Other varieties that have found favor in California have been the Folle blanche, Saint Emilion, and Sauvignon vert. Although these varieties lack the distinct flavor of the Pinots, they produce light wines with no particular disadvantages when grown under suitable conditions. Light-flavored varieties, such as Burger and Green Hungarian, which seldom get overripe, have also been used, especially for blending. Unfortunately, these are often too low in acidity and too vapid in taste.

Only a few Muscat-flavored sparkling white wines have been produced in California. These have usually been blends of a good white wine and a small amount of highly flavored dry wine made from Muscat Canelli or from other strongly flavored Muscat varieties.

The Pinot noir makes a satisfactory sparkling red wine, if it is not too low in acidity. The results in California, however, are often disappointing. Blends containing Carignane, Mondeuse, or Petite Sirah are acceptable when the grapes are picked sufficiently early. The red grapes should not be left on the skins too long, lest the wine be too astringent for early bottling. Usually a short fermentation will give sufficient color, since the sparkling red wines do not require a deep color.

Composition.—The volatile-acid content, especially, must be low—below 0.070 per cent. To secure wine of such low volatile-acid content, the makers customarily bottle their product in the spring following the vintage. Before bottling, the wine must be comparatively free from bacteria, since the secondary fermentation should be as clean as possible. Sulfur dioxide is objectionable because it hampers the progress of the secondary fermentation, has an objectionable odor, and produces nauseating compounds during the secondary fermentation in closed containers. Schanderl[74] has also found that too high an iron or copper

[74] Schanderl, H. Kellerwirtschaftliche Fragen zur Schaumweinbereitung. Wein und Rebe 20(1):1–8. 1938.

content or a deficiency of phosphate inhibits the secondary fermentation of German sparkling wines.

The finished still wine should be dry and contain about 11½ to 12½ per cent alcohol and above 0.70 per cent total acid. Wines below 10½ per cent alcohol have a poor carbon-dioxide-holding capacity, whereas those above 13 per cent are frequently difficult to referment. The grapes should therefore be picked before their juice shows a Balling much above 21. Before fermentation it is usually considered desirable to raise the acidity to 0.75 per cent or higher, since there will be a decrease during the finishing.

Clarification.—One important problem with the sparkling wine base is to get it brilliant as soon as possible after fermenting. Early clarification can be facilitated by making the original fermentation on as clear a must as possible. After the pressing, the must may be introduced into a settling tank; and, if the conditions are cold enough (either artificially or naturally), much of the extraneous matter will be precipitated. Fermentation of the clear liquid after separation from the precipitate will give cleaner and more easily clarified wines. As soon as the fermentation is completed, the wine maker must take steps to facilitate the natural clarification. Early and careful racking and lowering of the temperature are the first steps. Since the finished wine must be stable to freezing temperatures (sparkling wines are always chilled before serving), the excess tartrates must be removed either from the bulk wine before bottling or from the bottled wine at the time of disgorging (p. 101), by lowering the temperature. Since a light color is essential for the white sparkling wines, the racking must be done with the least possible aeration. Usually two or three rackings take place during winter and spring, the last of them being preceded by a fining. Any necessary blending should always be done before the fining and final racking. Isinglass, gelatin, and gelatin plus tannin have been the favored fining agents for champagne material. According to Pacottet,[75] filtration of the light, delicate wines of Champagne, France, is less desirable than fining.

Wines to be carbonated are used directly after clarification (see p. 103).

THE SECONDARY FERMENTATION IN GLASS

Addition of Sugar.—The chief purpose of the secondary fermentation in the bottle or in bulk is to produce sufficient carbon dioxide to give an internal pressure of 4–6 atmospheres (60–90 pounds per square inch). To secure this pressure, a secondary fermentation is conducted in a

[75] Pacottet, P., and L. Guittonneau. Vins de Champagne et vins mousseux. p. 111–12. Librairie J.-B. Baillière et Fils, Paris, France. 1930.

closed system from which the carbon dioxide cannot escape. After the wine has been introduced into large mixing vats, the desired amounts of sugar, yeast, and occasionally other substances are added. About 4.3 grams of sugar per liter will yield 1 atmosphere of pressure in the bottle. Wines of fairly high alcohol content will require slightly more sugar (4.3 grams of sugar per liter is equal to 1 pound of sugar in 27.9 gallons). The sugar content should be determined, and the proper deduction for residual sugar made. More accurate formulas for calculating the exact amount of sugar needed are given by the writers listed under "References on Sparkling Wines" (p. 135). The sugar is added as a 50 per cent solution. This is conveniently prepared by mixing 11 pounds of cane sugar and 1.81 gallons of wine, and ¼ pound of citric acid (see next section). The mixture is heated nearly to boiling to invert the sugar. When cool there should be 2.64 gallons of 50 per cent invert sugar —the *tirage* liqueur. A test bottling of the proposed wine with the calculated amounts of sugar and acid is advisable to check on the actual pressure obtainable. Gauges are available for measuring the bottle pressure; this type of gauge has a pointed stem that pushes through the cork.

Addition of Yeast, Acid, and Other Substances.—A pure culture of champagne-type yeast is required because of the firm sediment it produces. (The initial fermentation may also be very satisfactorily conducted with this yeast.) About 5 per cent by volume of a pure culture (p. 45) is added.

The most common addition, other than sugar and yeast, is citric acid, used to bring the wine to above 0.75 per cent total acid.

Occasionally, small amounts of tannin are added to facilitate the later "working down" of the sediment.

Slight amounts of color may be removed with decolorizing charcoal—but only in minimum amounts, lest the wines acquire an off-flavor. The charcoal is removed at the time of disgorging.

The wine, yeast, sugar, and other ingredients added are thoroughly mixed in large tanks before and during the bottling. Sometimes the mixture is allowed to stand overnight to permit the yeasts to multiply while the wine is still in contact with the air, but the whole mass is vigorously stirred throughout the period of actual bottling.

Bottling and Fermentation.—This is called the *tirage* bottling. Bottles capable of withstanding pressures up to about 9 atmospheres are required. They should be carefully examined visually, by knocking against one another, or by polarized light (see p. 110) and any defective ones eliminated.

The bottles are not filled so full as for dry wines, and special three-piece paraffined corks, called *tirage* corks, are used. The cork must not be too hard, or it will be difficult to remove at the time of disgorging. It is tapped only about one-half way into the bottle by a special machine. A steel clamp, called an *agrafe*, is placed by another machine over the cork so that it catches on the rim around the bottle neck. The clamp holds the cork in the bottle when the pressure develops. The bottled wine is then stacked so that no bubble of air remains in contact with the cork.

Quick fermentations in warm rooms may cause considerable breakage and also leakage around the cork. A cool fermentation yields a wine with a more satisfactory aroma. The important caves in Reims, France, have a maximum temperature of 54° Fahrenheit, but the yeasts used are probably acclimated to these temperatures. Temperatures up to 70° are sometimes used. Tarantola[76] found that the aroma, flavor, and persistence of the foam was increased by fermentation in the bottle at 41° Fahrenheit compared with fermentations made at about 60°. If new bottles are used and the fermentations conducted at moderate temperatures usually less than 3 per cent of the bottles break.

After about six months, when the fermentation is practically over, the stacks are torn down, the broken bottles removed, and the sediment well shaken. The bottles, when restacked, are so arranged that the lees will be deposited in the same place as before. During maturation in contact with the lees, the bottle may be shaken and repacked once or twice a year. By repacking the bottle so that the sediment always collects at the same place "masking" on all sides of the bottle will be prevented. A chalk mark is placed in the bottom of the bottle on the side on which the sediment collects to facilitate handling the bottles and returning them to their proper position.

In the early stages of fermentation, great care must be exercised to protect face and hands against flying pieces of glass from the breakage of faulty bottles. This danger is not entirely over until the wine is disgorged.

Disgorging.—The secondary fermentation produces a considerable sediment of yeast cells, tartrates, and the like. The simplest method of completing this precipitation is to lower the temperature to about 25° Fahrenheit for perhaps 2 weeks. The bottles are then ready for clarification, which is accomplished by gradually moving the sediment on the sides of the bottle on to the cork. The bottles are placed on end in special racks (fig. 17), and the sediment is worked onto the cork by twirling them rapidly to the right and left and dropping them back into the rack in the original position.

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[76] Tarantola, C. La preparazione dell' "Asti Spumante" con fermentazione a bassa temperatura. Annuario della Regia Stazione Enologica Sperimentale di Asti 2(II): 315–21. 1937.

If there is not too much pressure in the bottles, the actual disgorging is comparatively simple. The sediment and a portion of the liquid in the bottle neck are frozen solid by placing the neck in some liquid (usually glycerin) cooled to below –12° Fahrenheit. The agrafe is then removed, and the plug is forced out by the gas pressure in the bottle. Only a little wine is lost by this procedure unless the pressure is very high, but an atmosphere or more of pressure is lost during the disgorging. The disgorger not only removes the cork and makes sure that all sediment is ejected, but also smells each bottle as it is opened and eliminates the

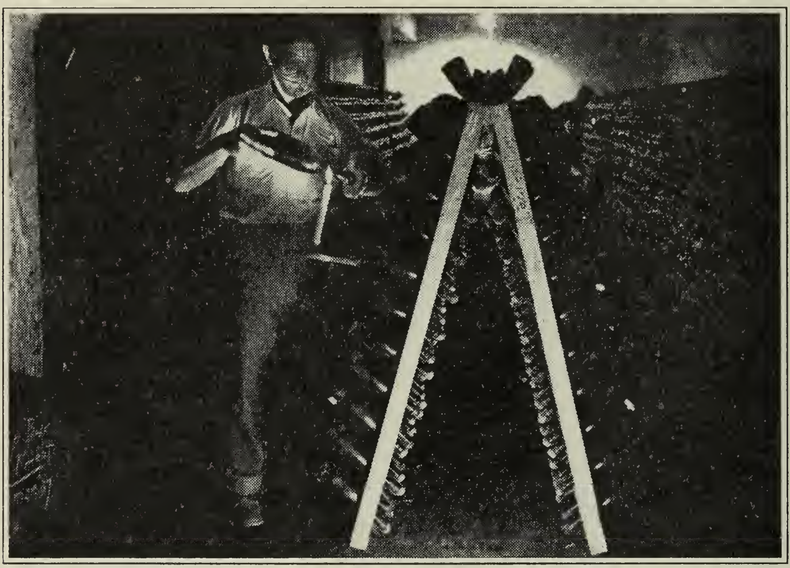

Fig. 17.—Candling champagne during the *remuage* to determine the movement of sediment onto the cork. Note the type of rack used to facilitate settling, steel clamps, *agrafes* on corks, and the mask to protect the workman. (Photograph by courtesy of the Wine Institute.)

bad bottles. Some wine makers prefer not to freeze the neck, but ferment the wine to a higher pressure and blow the sediment out. More pressure and wine are lost by this system.

Sweetening.—The wine after disgorging is free of sugar and very dry in taste. To satisfy the customers' palate, 1 to 3 per cent of sugar is usually added, the better-quality champagnes being left the driest, whereas the wines with a less desirable flavor are more generously sugared (up to 10 per cent).

Each firm has a slightly different formula for preparing the liqueur from pure sugar, aged wine, and usually 5 to 6 per cent of good-quality brandy. (This liqueur averages somewhat sweeter than the 50 per cent *tirage* liqueur previously mentioned, p. 100.) The mixture must be filtered until absolutely brilliant. Immediately after disgorging, the sweetening liqueur (called the *dosage*) is added. Liqueuring machines automatically add a given measured amount of the liqueur and, if necessary, wine of the same type to replace that lost during disgorging.

FERMENTATION IN LARGE-SIZED TANKS

Fermentation in large-sized containers makes it possible to produce a large volume of uniform sparkling wine at a lower cost than by the regular champagne method. The results differ because of the reduced time the wines are left in contact with the lees in the large containers.

The tanks vary in size from 50 to 500 gallons and are ordinarily of steel lined with glass or with acid-resistant metal; they must be capable of withstanding high pressures. Within the tanks—or, if they are double-walled tanks, between the walls—are provided means of cooling or heating the fermenting wine. The fermentation can thus be closely regulated.

The same type of wine, yeasts, and sugar solution used for the bottle fermentation should be employed (p. 100). As soon as the pressure reaches the desired amount, the wine is chilled to check fermentation. Escape valves are also available so that excessive pressures can be prevented. The wine may be clarified in the tanks and then run through special filters without loss of pressure into the bottle. The desired sweetening agent may be added to the bottles before filling under pressure.

CARBONATION

Artificially charged wines are made from brilliant wines sweetened with the proper amount of sugar, and then charged with carbon dioxide gas in a suitable carbonating machine. This usually consists of a chamber in which the gas is introduced as a fine stream into cold wine which is agitated, or the wine may be charged by flowing from one bottle to another over a series of balls or baffles through which carbon dioxide is rising under pressure. For best results the wine must be cold (about 32° Fahrenheit) and the apparatus properly constructed and operated. Properly carbonated wines will not lose their gas immediately after opening. The corking and capping operations are as described in the next section.

CORKING AND CAPPING

The bottle is closed with a cork of high quality. The corks may be rinsed in alcohol, washed in cold water (but not in hot), and drained before use. As before, the cork is placed only about one-half way in the bottle. These corks are often branded with the producer's name.

To hold the cork in, a wire cap (*muselet*) is then placed on a metal plaque over the cork. A large capsule is put over the entire end of the bottle when the wine is labeled, so that the wire and the cork do not show. After corking and wiring, the bottle should be shaken so that the sugar and wine are well mixed.

AGING AND STORAGE

Champagnes and similar effervescent wines undergo aging in two stages, either during the period before disgorging or after. Practice in this respect varies. Champagnes are preferably allowed to age for two or three years in contact with the lees in the bottle, little aging then being required after disgorging. In some California wineries the champagnes are disgorged young and must then be aged in the bottle for three to five years. Carbonated wines usually are not aged. Bulk-fermented wines can only be aged in the bottle after removal from the tank, for it is not practical to maintain the wine in contact with the lees because of the expensive equipment.

Champagnes and other effervescent wines stored on their side should, if properly cooled, remain in good condition for at least ten years. The limiting factor is the loss of pressure caused by leakage of the corks.

PREPARATION FOR MARKET[77]

TASTING

The examination of the wines by a wine taster in the cellar should be a regular practice. By this means the wine maker can follow the development of the wine, detect incipient spoilage, establish the type and quality of wine, and eventually decide upon the necessary treatments and blends as well as upon the time of bottling. Successful tasters should be able to differentiate shades of color and flavor. The tasting is best done in a clean, well-lighted room away from foreign and winery odors. Chemical analysis can confirm the results of tasting as to the soundness of wine but will not necessarily confirm the results as to quality.

Appearance.—The first step in inspecting a wine is to examine its appearance, which indicates its condition. Tulip-shaped, thin-walled glasses (fig. 18) are satisfactory in tasting. Frequently the nature of the sediment or cloudiness will indicate the specific, immediate treatment necessary. Various diseases have characteristic forms of clouding, which the taster soon learns to recognize.

From the color, the taster can gain additional information. White wines that have become brown have usually been affected by overaging or overaeration. Old white wines turn darker, but more golden than brown. Old red wines show a slight browning, quite characteristic and

[77] General references on this subject are listed on page 136.

unobjectionable. High-acid wines always have an especially bright-red color not found in low-acid wines. The first indications of the type of wine are given by the color. Light- and dark-colored wines are quickly differentiated. Certain wines have distinctive tints, easily distinguished. Where dyes have been added, these can sometimes be identified.

Odor.—After a careful visual inspection, the wine is smelled. Many diseases impart characteristic odor, quickly recognized. Wines with high volatile acid, hydrogen sulfide, sulfur dioxide, and the like, can all be distinguished by smell alone.

Flavor.—The actual tasting should be made with a very small quantity of liquid. By drawing air in and over this liquid in the mouth, the

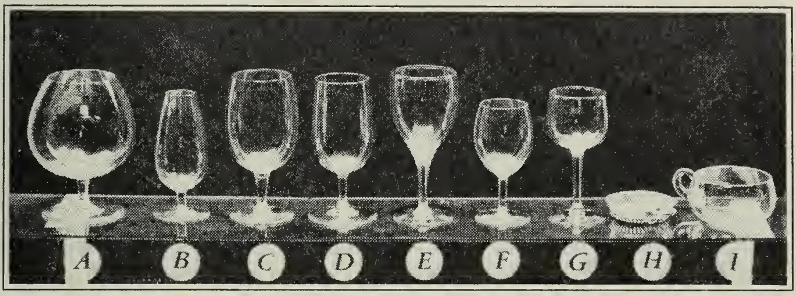

Fig. 18.—Cups and glasses used in tasting wine: *A* and *B*, narrow-brimmed glasses used mainly for smelling wines; *C* to *G*, glasses used for tasting; *H* and *I*, silver and glass cups largely used to observe the color of red wine.

aromas are brought out. Sweetness, astringency, metallic flavors, and other qualities can be identified. The degree of smoothness of red wines is frequently an indication of how long it must be aged before bottling.

The tasting results should be compared with chemical analysis. It is psychologically important not to look at the analytical record before the tasting. Accurate tasting may be used as a guide as to the extent of chemical analysis necessary. The wine maker can then decide on the treatments necessary for the wines. To gain confidence and skill, the taster should record his results and check them by a later independent tasting.

MICROSCOPIC EXAMINATION

Miscroscopic examination of fermenting musts and wines is often useful in detecting the presence of undesirable microörganisms. It is of limited diagnostic value by itself because mere inspection will not differentiate between living and dead cells, and between desirable and undesirable ones. Changes in the microflora both as to type and number during fermentation or storage and the presence of abnormal forms are more significant. Incubation of samples of suspected wines with periodical microscopic examination will reveal the presence of viable forms capable of developing in wines. These observations should be confirmed by the usual bacteriological technique of isolating and identifying the organisms present.

ANALYSES

A knowledge of the composition of wine is of value not only in blending but also in determining soundness, palatability, and keeping quality. Though accurate enough for control purposes, the methods described below have been chosen, in so far as possible, for simplicity and speed rather than extreme accuracy. They have been written for persons familiar with, but not necessarily skilled in, laboratory technique.

Alcohol by Ebullioscope or Ebulliometer.—The method is based on the regular variation in the boiling point of mixtures of alcohol and water with alcohol content. For ordinary wines with low-to-medium extract, the wine is introduced directly into the ebullioscope, and the boiling point is observed. For dry wines of high extract content, dilute 1:1, and multiply the result obtained with this diluted wine by 2. As the boiling point of water varies with the atmospheric pressure, it must be ascertained at the time each series of determinations is made. A sliding scale, on which the boiling point may be adjusted, accompanies the instrument and is used for calculating the alcohol content.

Total Acid.—For white wines: Pipette 10 cc (cubic centimeters) of wine into a 500-cc flask, and add 250 cc of boiling distilled water. Add 3 to 5 drops of phenolphthalein indicator solution; and titrate with standardized 0.1 *N* NaOH (0.1 normal sodium hydroxide) to a distinct pink color, or until 1 or 2 drops of hydroxide produce no perceptible change. One may observe the color change by holding the flask just above a well-lighted white surface. The total acidity, expressed as grams of tartaric acid per 100 cc, is obtained by multiplying the number of cubic centimeters of 0.1 *N* NaOH used in titration by 0.075.

For dark and red wines: Measure 2.0 cc of wine into a 500-cc flask. Add 250 cc of boiling distilled water and several drops of phenolphthalein indicator. Disregard the red to bluish-black color change, and titrate with 0.1 *N* NaOH to a pink end point. The total acidity expressed as grams of tartaric acid per 100 cc is obtained by multiplying this titration figure in cubic centimeters by 0.375. For this titration, a microburette is preferred, although a 10-cc burette graduated in $\frac{1}{20}$-cc intervals is satisfactory. More dilute NaOH may be used also, for example, 0.033 *N*. In this case a regular burette may be used.

Volatile Acid.—The method is based on the fact that the volatile acids of wine are distillable by steam at atmospheric pressure. With a 10-cc pipette, introduce 10 cc of wine into the central tube of a volatile-acid distillation apparatus. Add 150 cc of recently boiled hot distilled water to the outer flask. Tightly connect the apparatus as directed by the manufacturer. Start cold water running through the condenser, and apply heat to the outer flask. When the water has boiled for a moment, close the pinchcock on the outlet of the outer flask, and distil until 100 cc has been collected in a 300-cc flask. Heat the distillate to boiling, add 3 to 5 drops of phenolphthalein solution, and titrate with 0.1 *N* NaOH. The volatile acid content as grams of acetic acid per 100 cc of wine is obtained by multiplying the titration in cubic centimeters by 0.06. Somewhat more accurate results may be obtained for the titration by using a more dilute NaOH solution.

Extract.—Pipette 100 cc of wine into a 250-cc beaker, add 50 cc of distilled water, place over the source of heat, and evaporate to approximately 50 cc volume. Remove from heat and cool to room temperature. Dilute back to the original volume in a 100-cc volumetric flask by adding distilled water. Adjust the temperature to exactly 68° Fahrenheit and then place a portion of the liquid in the glass hydrometer cylinder. Read off the approximate extract with a Brix hydrometer. When the dealcoholized wine has been adjusted to the same volume as that of original sample, the Brix reading gives the approximate extract direct as grams per 100 cc of wine.

Reducing Sugars.—The volumetric method given below is based on the Lane and Eynon titration method for determining substances capable of reducing copper in alkaline tartrate solution. Although the copper-reducing substances in wine are largely sugars, other reducing matter is present and must be removed. The standard procedure is to clarify with lead acetate and then remove excess lead. The treatment with charcoal given here is simpler though less accurate.

Dealcoholize the wine (as for extract), cool, and make to the original volume by adding distilled water. With white wine, filter if not brilliantly clear. With red wine, decolorize by shaking 100 cc of wine with about 5 grams of acid-washed, decolorizing carbon and then filtering.

Immediately before use, prepare the Soxhlet reagent by mixing 50 cc each of Fehling's A and B solutions in a clean, dry flask.

Pipette accurately 25 cc of the mixed Soxhlet reagent into a clean 300-cc Erlenmeyer flask. To standardize the method, fill the burette with a standardized 0.5 per cent dextrose solution and also pipette 20 cc of this solution into the flask. Set the burette over the flask on a wire gauze. Heat the cold mixture to boiling on a wire gauze and maintain a moderate boiling for about 15 seconds; lower flame enough to avoid bumping. Add rapidly further quantities of the sugar solution from the burette until only the faintest perceptible blue color remains. Without removing the flame, add 2–5 drops of 1 per cent methylene blue solution; and titrate dropwise until the indicator is completely decolorized. The total volume of the standard solution necessary should be about 24 cc.

To determine the sugar content of the wine, proceed as above, adding 20 cc of the prepared wine solution to 25 cc of the mixed Soxhlet reagent. After boiling it for 15 seconds, finish the titration by adding standard dextrose solution from the burette. If the 20 cc of wine solution completely decolorizes the Soxhlet reagent, dilute the wine solution further, and repeat the determination. For example, take 20 cc, dilute to 100 cc, and take 20 cc of the diluted liquid, multiplying the result by 5 in this case.

From the amount of the standard dextrose solution necessary to reduce the copper completely and from the amount necessary to finish the reduction after the addition of the wine solution, the sugar content of the latter can be calculated as follows:

Per cent copper reducing matter as dextrose in the wine solution = (cubic centimeters of dextrose for direct titration – cubic centimeters of dextrose for back titration) $\div$ 20 $\times$ 0.5.

Tannin and Coloring Matter.—The method depends on the determination of the permanganate reducing matter of the wine before and after decolorization with carbon.

Dealcoholize the wine, cool, and make to the original volume. Transfer 2–5 cc, according to the color, to a 800-cc beaker. Add about 500 cc of water and exactly 5 cc of indigo solution. Titrate with standard $KMnO_4$ (potassium permanganate) solution, 1 cc at a time, until the blue color changes to green; then add a few drops at a time until the color becomes golden yellow. Thoroughly stir the solution with a glass rod after each addition. Designate the cubic centimeters of $KMnO_4$ solution required to reach the golden-yellow color, using the dealcoholized wine as *a*. Decolorize and detannize a portion of the dealcoholized sample by shaking well with carbon. Filter and titrate the same volume as was used previously, with $KMnO_4$. Designate the number of cubic centimeters of $KMnO_4$ used for the dealcoholized, decolorized, and detannized sample as *b*.

Then $a - b = c$, the number of cubic centimeters of $KMnO_4$ solution required for oxidizing the tannin and coloring matter in 2–5 cc of the wine. The amount of tannin as grams per 100 cc of wine is equal to

$$c \times \text{normality of } KMnO_4 \times 0.0416 \times \frac{100}{\text{volume of wine}}$$

Sulfur Dioxide.—The total sulfur dioxide is best determined by distillation. To a 50-cc sample of wine, add 200 cc of water, 10 cc of concentrated HCl (hydrochloric acid), and 10 cc of saturated $NaHCO_3$ (sodium bicarbonate) solution, then distil into 50 cc of a freshly standardized 0.02 *N* solution of iodine in an Erlenmeyer flask cooled with ice water. After 150–175 cc of distillate is collected, determine the residual iodine by titration with standard 0.02 *N* $Na_2S_2O_3$ (0.02 normal sodium thiosulfate), using a few drops of freshly prepared starch solution as the indicator. In the same way, determine the volume of $Na_2S_2O_3$ solution initially required to reduce 50 cc of the iodine. Then the difference between the initial and final $Na_2S_2O_3$ titration value of the iodine solution, multiplied by 12.8, gives SO_2 content in milligrams per liter or parts per million.

BLENDING

Where the character and composition of the grapes used in wine making are known and uniform, the blending is done when the grapes are crushed. Most frequently, however, the wines must be blended also. Blending is used to produce standarized wine of a certain type, to accentuate a special flavor, or to balance the wine. Wines with too much or little acid, too low or high in body, and so forth, may be improved by blending. The improvements in quality and uniformity of wine which are possible by a careful blending of selected wines in the cellar, are too often overlooked.

With blending tests, the taster must have the desired result clearly in mind. Haphazard blending is of little value and may do considerable damage to wines of desirable characteristic flavors. Furthermore, the final chemical composition of the desired product will make certain blends impossible from the stock at hand. Therefore, only the wines that are basically suitable need be considered. Certain blends will be impractical if the wine is too expensive or because of its quality and age. In deciding upon a blend, only a little of each wine is necessary; but this must be very accurately measured. After a desired combination is found, a test blending should be made. Several gallons of the blend may be mixed well in a small keg and stored for a few days. The final tasting will then reveal any remaining deficiencies.

Even though all components of the blend may have been brilliantly clear before mixing, either a clouding or a precipitation will often occur after blending. Sometimes this change is due to the actual precipitation of tartrates or the formation of casse; at other times it results from overaeration and is cured by standing. If the wine should not remain clear, either in the wood or in test bottlings, it may have to be re-fined, filtered, or otherwise treated. The blend should always be stored for several weeks before bottling.

Although blending is a great advantage to the wine maker—for instance, in permitting him to standardize his types—it is not a cure-all. Bad wines, even in small amounts, may contaminate or dilute good ones; and the good wine will thus depreciate in value. The desirable characteristic flavors of certain wines may be diluted beyond recognition, or masked by other less desirable flavors.

BOTTLING

The object of bottling is to preserve the wine by protecting it from the action of microörganisms and oxygen, to bring about secondary aging, and to facilitate distribution.

Not only must the bottle be well chosen for consumer acceptance and sales appeal, and the wine be of suitable quality, age, and clarity, but also the actual operation of bottling from filling to labeling should be carefully supervised. Fine, sound wines are often spoiled by unnecessary or extreme aeration during filling; by infection with bacteria, yeasts, or molds; or by faulty closure. *Sanitation in bottling, as well as in wine making, cannot be too strongly stressed.* The more important steps in bottling still wines are final clarification or filtration, choice and preparation of bottles, filling, closing, pasteurization (in some cases), labeling, and casing.

Preparation of Wine for Bottling.—Only sound wine, properly aged, should be bottled. There is a tendency to bottle wines rather young, both here and abroad, and, if such wine is properly mellowed and stabilized, bottling need introduce no difficulty in respect to clearness and keeping quality. Just before bottling, the wine usually undergoes a final clarification or close filtration. Many wine makers prefer to fine their wines with isinglass in order to produce a crystal-clear brilliance. The final step before bottling, however, is usually a close filtration.

Bottles.—The bottles must be carefully selected, not only for size and shape suitable to and offering the best protection for the type of wine, but also for strength and freedom from defects. The latter is particularly necessary when bottling is done mechanically. The glass should be of the proper hue as dictated by custom—clear white, greenish or brown, according to the type, for white wines; dark green for red wines (fig.

19). It should be without flaws and air bubbles, uniform in thickness, and free of strains. Abnormalities and defects in glass are readily observable when the bottle is examined by polarized light. This is easily done by placing the bottle in front of a lighted surface and observing the bottle through spectacles which have polarizing lenses. The necks should be properly blown to suit the type of corkage or seal desired.

The bottles, of whatever design, should be thoroughly cleaned and as

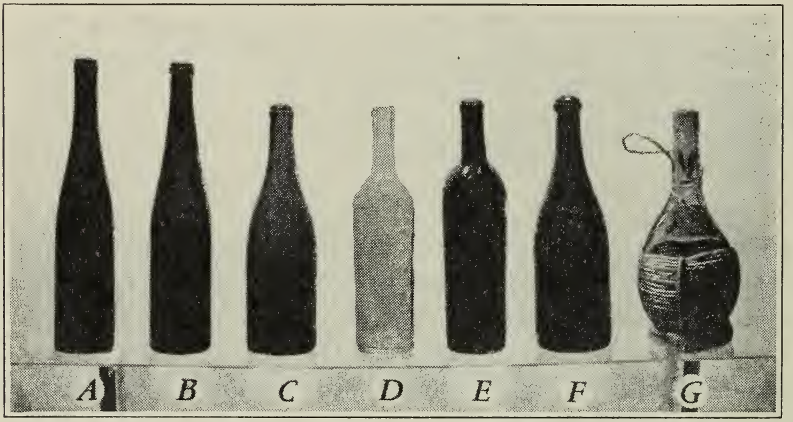

Fig. 19.—Bottles used for table wines: *A*, green bottle used for California Riesling, hock, and Rhine wines; *B*, brown bottle used for California Moselle wines; *C*, green bottle used for California Burgundy and Chablis wines; *D*, a nearly white bottle used for California sauterne wines; *E*, green bottle of the same shape as *D*, used for California claret, Cabernet, and Zinfandel wines; *F*, a heavy, green bottle used for champagne and other sparkling wines; note the heavy glass rim for holding the steel clamp on; *G*, a light-green *fiasco* used for California red and white Chianti wines.

nearly sterile as possible. After being washed with a suitable detergent solution—soda ash, trisodium phosphate, or metaphosphate solution—they should be rinsed with clean, sterile water. The directions given by the manufacturer for the use of the particular detergent selected should be carefully followed and the bottles washed until free from all adherent foreign matter. No trace of chemical which would affect the stability, odor, or flavor of wine should be left in the bottle. The washed bottles should be allowed to drain dry before filling, but they should be filled shortly after drying and not allowed to become dusty or contaminated. The practice of rinsing bottles with wine before filling is not desirable because of the possibility of spreading infection.

Filling.—In filling the clean, dry sterile bottles with the freshly clarified or filtered wine, one should, again, be careful to avoid infection, excessive aeration, and contamination with metallic impurities. The bottling room should be well lighted, well ventilated, and scrupulously clean. The fillers should be thoroughly cleaned, sterilized, and rinsed with a little of the wine before use. Discard and do not re-use the rinsing wine. The wine should not come in contact with any metal parts made of iron or other corrodable metals. Siphon fillers with spouts long enough to reach well to the bottom of the bottle, or other proved fillers, should be used, and the bottles filled from the bottom up. Although many automatic bottle fillers actuated by vacuum are being used, most of the wineries still retain a siphon filler. Too much air space should not be left in the neck of the bottle, for it permits undue oxidation of the wine.

Corks and Corking.—The closure preferred by custom for dry table wines is the straight, untapered wine cork at least 1½ inches long. A 2-inch cork, or longer, is used for choice wines to be stored for long periods. Successful closure depends on selecting corks of the highest quality and of the right size, on properly softening and preparing the corks, on the use of wine bottles with the proper "corkage" (that is, with a neck free from grooves, bumps, or other inperfections and properly tapered), and on properly driving the cork into place. Freshly cut corks contain not only particles of cork dust adhering in the small pores or cavities but also soluble gallic acid, iron gallate, nitrogenous and fatty matters, and other substances that impart a disagreeable corky taste. In addition, the corks, especially the poorer and more open ones, are generally infected with resistant mold spores, yeast, and bacteria that may and occasionally do develop in the wine. Before use, the loose cork dust and cork extractive must be removed, the corks sterilized, and softened. This is accomplished by soaking an hour or more in a cold, dilute (1 per cent) solution of sulfur dioxide containing a little glycerin, and rinsing well in clean water. They should be well drained before use.

The corking machine operates in two stages: first, the cork is compressed to a small cylinder by the operation of horizontal movable jaws, or stationary jaws and plunger; and next, the compressed cork is driven into the bottle by a vertical plunger. The best type of corker is one that compresses the cork from all sides by jaws closing uniformly like the iris of a camera lens, although machines in which the cork is rolled as it is compressed from three sides by movable jaws are also satisfactory. Stationary-jaw, horizontal-plunger type compression is less desirable because of the danger of pinching or irregularly compressing the cork. As the cork is compressed, if it is not dry, drops of moisture ooze out from the bottom; these must be wiped off to prevent contamination of the wine.

Screw Caps.—In addition to straight corks, screw caps are used as closures, particularly for the ordinary table wines. These are available in a variety of types and patterns. When screw caps are used, particular attention should be paid to the finish on the neck of the bottle. The cap should seat properly and seal the bottle completely.

Capsuling.—To prevent insect infestation of the top of the exposed cork and to make the seal more airtight, it was once customary to seal off the top with beeswax. Nowadays, however, imported and domestic metal foil caps are placed over the neck of the bottle and crimped into place in a special machine.

Inspection and Storage Tests.—Finally, before labeling and packing, each bottle must be carefully inspected in a strong light for undesirable haze, cloud, or sediment. Freshly bottled wine should be stored for at least several weeks before the final inspection in order to give it time to recover, show disease, or throw down sediment. Changes can be hastened by storing some bottles at 90° Fahrenheit in an incubator and some at 32° in a refrigerator. Large bottlers will, therefore, find it very profitable to install such testing equipment and to incubate and refrigerate samples of each lot of wine bottled.

LABELING

The nomenclature for California wines has never been standardized. Many of the present type names originated abroad. The advisability of the use of such foreign names as "Burgundy" and "sauterne" by California producers, has often been questioned. Undoubtedly it would be desirable to develop native names for distinctive types. Such a nomenclature would stimulate the production of native wines of more standardized composition and quality. Several type names already widely used—for example, Angelica, Zinfandel, and Riesling—are not derived from any foreign geographical appellation, but originated in California or were derived from names of varieties of grapes. A number of wineries also have developed proprietary names for their wines. These are encouraging developments.

In selecting a type name and label, the producer should be guided by the existing state and federal restrictions as well as by the character and composition of the wine. Quality wines usually have vintage labels.

Type Names for Dry Red Table Wines.—California Burgundy is a type name which has been utilized for heavy-bodied, dark-colored, dry, red table wine. In the district where it originated, it was produced from the Pinot noir variety with or without mixture with the Gamay. The Petite Sirah has been used in this state, for this type of wine. If this were uniformly followed and if the Petite Sirah were not used for any other type of wine, its varietal flavor would constitute a good point of differentiation for this type of wine. The analyses of table 20 show that there has been considerable overlapping in the composition of the types California Burgundy and California claret, especially with regard to what is usually considered a good point of distinction, namely color.

In general, however, California claret has come to be applied to red wines of no predominant characteristic flavor or aroma, and which contain less color and extract than California Burgundy. Originally "claret" was used for the red wines of Bordeaux, which are largely derived from the Cabernet Sauvignon variety. In this state, wines so produced receive the name of this variety.

California Cabernet is a distinctive type of wine produced from at least 51 per cent of the Cabernet Sauvignon variety and possesses the predominant aroma and flavor of that grape. As table 20 indicates, it is a moderately colored wine of good extract and alcohol.

Other dry red table wines which take their name from a grape variety are the California Barbera and Zinfandel. These likewise must derive at least 51 per cent of their volume and their predominant aroma and flavor from the respective varieties. The Barbera is a favorite grape from the Piedmont district of northern Italy. It should produce a full-bodied, very tart wine, since it has the highest total acid of any of the common red wine-grape varieties. The California Zinfandel is of unique California usage; it is most easily recognized by its distinctive, berrylike aroma and flavor. It is apparently most pleasing when consumed young. It should not possess a residuum of sugar.

California red Chianti is a type name which has been used for fairly heavy, moderately astringent, red wines. It is usually bottled in a raffia-covered bottle. The red Chianti of Italy largely owes its character to the variety Sangioveto, which has also occasionally been used here with some success in making a distinctive red wine. California red Chianti, in contrast to California claret and Burgundy, should be a piquant, fruity wine and preferably should have a distinct flavor of the Sangioveto or other Italian varieties.

Type Names for Dry White Table Wines.—California Chablis is used for wines of dry, fruity character and medium tartness. In France this type is produced almost entirely from Chardonnay grapes. California producers of wines of this variety have usually labeled them with the name of the grape.

As table 20 indicates, there is considerable overlapping in the composition of California hock and Moselle. For this reason it is very difficult to suggest distinctive differences which would be uniformly true in the industry. As a preliminary basis of distinction, some producers have successfully used "California Moselle" for the wines of more distinctive character having at least some flavor of the Riesling grape. Both types should be of fairly low alcohol, seldom over 12 per cent, and of high

TABLE 20

Analysis of Certain California Red and White Table Wines Submitted to the 1937 and 1938 California State Fairs

Wine	Number of samples	Range or average	Volatile acid as acetic	Total acid as tartaric	Alcohol	Extract	Sugar	Tannin	Color*
			grams per 100 cc	*grams per 100 cc*	*per cent*	*grams per 100 cc*	*grams per 100 cc*	*grams per 100 cc*	
Dry red table wines:									
California claret	39	Range	0.064–0.176	0.45–0.78	11.3–16.0	2.4–7.2	0.09–5.00	0.12–0.3	10–37
		Average	0.102	0.64	12.4†	2.9†	0.25†	0.20	18
California Burgundy	48	Range	0.056–1.74	0.46–0.88	10.8–13.6	2.1–4.4	0.12–1.90	0.13–0.37	7–45
		Average	0.099	0.65	12.6	2.9	0.30	0.23	15
California red Chianti	13	Range	0.080–0.136	0.63–0.79	9.3–13.5	2.3–3.4	0.27–1.13	0.15–0 32	8–31
		Average	0.106	0.69	12.1	2.8	0.33	0 26	18
California Barbera‡	4	Range	0.068–0.104	0.52–0.63	11.8–13.0	2.5–3.3	0.15–0.23	0.19–0.28	18–23
		Average	0.079	0.63	12.2	2.9	0.18	0.23	19
California Cabernet	21	Range	0.086–0.226	0.48–0.82	11.3–13.4	2.4–3.8	0.10–0.72	0.15–0.31	9–39
		Average	0.118	0.64	12.6	2.9	0.20	0.24	16
California Zinfandel	31	Range	0.054–0.156	0.45–0.81	11.5–13.3	2.3–3.4	0.11–0.68	0.12–0.36	7–37
		Average	0.095	0.64	12.5	2.8	0.22	0.20	17
Dry white table wines:									
California hock	12	Range	0.042–0.112	0.51–0.67	11.1–13.3	2.3–3.2	0.09–0.18	0.02–0.08	...
		Average	0.088	0.59	12.1	2.5	0.14	0.05	...
California Moselle	14	Range	0.055–0.102	0.45–0.69	11.3–13.1	2.1–3.3	0.15–0.29	0.03–0.08	...
		Average	0.077	0.55	12.2	2.5	0.20	0.06	...
California Riesling	35	Range	0.040–0.178	0.40–0.69	11.0–14.2	2.1–2.9	0.11–0.28	0.03–0.09	...
		Average	0.092	0.56	12.2	2.5	0.18	0.05	...
California Chablis	31	Range	0.045–0 124	0.42–0 73	10 2–12.9	1 9–3 0	0 09–0 42	0 02–0 08	[illegible]
		Average	0.088	0.56	11.9	2.5	0.19	0.05	[illegible]

California white Chianti	10	Range	0.048–0.106	0.50–0.63	11.4–13.0	2.2–3.2	0.14–0.46	0.03–0.08	...
		Average	0.086	0.55	12.0	2.6	0.23	0.06	...
California Traminer	2	Range	0.062–0.100	0.51–0.57	12.0–13.4	2.5–2.8	0.20–0.26	0.07	...
		Average	0.081	0.54	12.7	2.65	0.23	0.07	...
California Sauvignon blanc	1	Average	0.088	0.55	12.9	2.35	0.12	0.06	...
California Golden Chasselas	8	Range	0.074–0.098	0.46–0.56	11.4–13.8	2.1–2.6	0.15–0.22	0.05–0.10	12–26
		Average	0.084	0.50	12.7	2.4	0.17	0.07	...
Natural sweet table wines:									
California dry sauterne	51	Range	0.039–0.178§	0.35–0.71	10.7–13.4	2.0–5.3	0.11–3.00	0.02–0.13	...
		Average	0.094	0.53	12.3	3.0	0.78	0.05	...
California sweet sauterne	29	Range	0.068–0.140§	0.39–0.96	10.1–14.5	2.2–7.6	0.14–5.46	0.03–0.11	...
		Average	0.092	0.60	12.4	5.2	3.05	0.06	...
California Chateau	18	Range	0.068–0.160§	0.39–0.69	10.2–13.7	2.6–7.9	0.32–5.60	0.03–0.11	...
		Average	0.108	0.59	12.1	5.7	3.62	0.06	...

* These figures represent the relative intensity of color expressed on an arbitrary scale; the higher the figure the greater is the concentration of pigment.

† Average does not include highest values. ‡ Samples for 1938 only. § Not corrected for sulfur dioxide content.

total acid, seldom below 0.7 per cent. They may accordingly be differentiated from California Chablis by their lighter body, higher total acid, and fruitier flavor, and from each other by the Riesling flavor of the California Moselle.

California Riesling is a type name used for dry white wines which are made from at least 51 per cent of Riesling grapes and which derive their predominant flavor and aroma from these varieties. Since the Riesling flavor is rather easily covered in blends, the wine should be predominantly derived from these varieties. The greatest successes have been achieved in California with the White Riesling (commonly called Johannisberger Riesling in California) and the Sylvaner (Franken Riesling), which are the most distinctive. Some producers have even avoided using the Riesling label on wines of the Wälschriesling, Kleinberger Riesling, and particularly the Gray Riesling, because, although these grape varieties produce mild, pleasant wines that easily fit the designations "California Moselle" and "California hock," they ordinarily disappoint those who desire Riesling. The desirable characteristics of distinctive flavor and aroma for Riesling wines are not ordinarily obtained from grapes grown in warm regions.

Other types of wine which take the name of the variety from which they are predominantly derived and which appear to be distinctive and satisfactory for use are the California Sauvignon blanc and California Traminer. The former has a highly individualistic aroma and a unique aromatic flavor. It is a heavy-bodied wine of high alcohol and medium acidity. The latter has a musky, aromatic aroma and flavor and is most pleasing when it has only moderate alcohol content and an acidity of about 0.7 per cent.

Another type of varietal-flavored white wine which has a place in the California wine industry is that which derives its flavor from one of the Muscat varieties. Varieties such as Muscat Canelli and Malvasia bianca have been used more successfully than the extensively planted Muscat of Alexandria. The latter variety is deficient in total acid and in dry wines its flavor is readily lost. The best balanced and most pleasing of these wines are those which contain one or two per cent of residual sugar, and a total acid content of at least 0.55 or 0.60 per cent.

California white Chianti is a dry, white wine which is bottled in the same kind of flask as California red Chianti. In Tuscany (Italy) it is produced from Saint Emilion (Trebbiano) and a Muscat-flavored grape. It can probably be differentiated from the other nonvarietal dry white wine types by a slightly higher astringency produced by the method of fermentation, and by inclusion of a slight Muscat flavor.

Type Names for Natural Sweet Table Wines.—Three white, natural sweet wines are produced in California, namely California dry sauterne, California sweet sauterne, and California Chateau type. As indicated in table 20, these may be differentiated from each other according to the percentage of sugar which they contain. California dry sauterne should contain less than 1 per cent sugar; California sweet sauterne should have from 2 to 3 per cent sugar, and the Chateau type at least 4 per cent sugar. The better-quality wines of this type in the Sauternes district of France as well as in California have been made mainly from Semillon grapes with lesser amounts of Sauvignon blanc. The type name California Haut Sauterne is usually used for a wine of similar composition to that of California sweet sauterne.

A pink-colored, natural sweet wine called Aleatico and made from Aleatico grapes is also produced in California. It should contain about 2 per cent sugar and have a delicate and distinctive Muscat flavor.

Type Names for Sparkling and Carbonated Wines.—Definitions of California champagne and California champagne bulk-process, and California sparkling Burgundy have already been given (see p. 97). These wines are produced by secondary fermentation in closed containers. In addition to the types mentioned, sparkling Muscat is also occasionally produced by this process. It is customary to indicate on the label the degree of sweetness and, in the case of the better-quality wines, the vintage on sparkling wines. The terms *"brut,"* "dry" (or *"sec"*), and *"demi doux"* are used to indicate increasing amounts of *dosage* in the wine.

California carbonated Moselle and California carbonated Burgundy are most commonly used and approved for carbonated white and red wines and appear to satisfactorily cover the label requirements. Permission to use "sparkling" as well as "carbonated" has been applied for.

Other Type Names.—Individual companies may desire to produce distinctive types of wine either from special varieties or by unique processes and to label them with type names other than those mentioned above. In using such proprietary and varietal names, the producer should not only consider securing approval from the proper governmental authorities but should also consider whether the type represents a desirable contribution to California wine nomenclature and, if named after a variety, whether the grapes are correctly identified.

As already indicated (see page 25), the character of the varieties which may be used for producing varietal types of wine changes considerably from season to season and district to district. In order, therefore, to protect the consumer, sufficient information concerning place of production and vintage should be given for types of wines which carry varietal names. See page 28 for additional varietal type names.

WINERY BY-PRODUCTS[78]

POMACE

The stems, pressed pomace, and lees are the main by-products of the fermenting room. The stems amount to about 3 per cent of the weight of the fruit. According to Rabak and Shrader,[79] they are rich in tannin and cream of tartar; but their possible commercial use is doubtful in California, and they are usually disposed of by scattering them in the vineyard, where they rapidly dry up. They should not be allowed to accumulate around the winery, since they rapidly acetify.

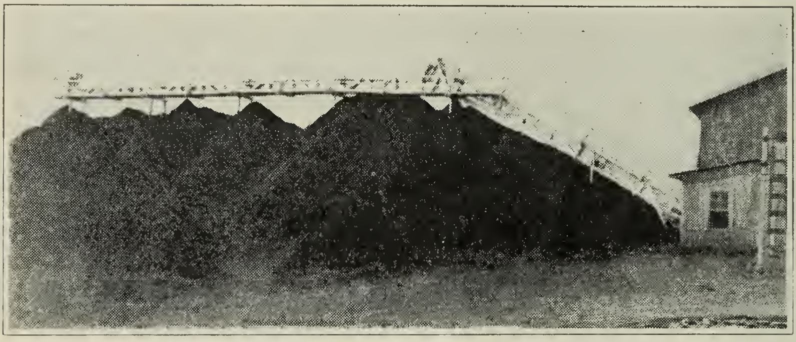

Fig. 20.—Pomace conveyor and pomace pile outside a large winery. Accumulations such as this are undesirable. (Photograph by courtesy of the Wine Institute.)

The pressed pomace constitutes 15 to 20 per cent of the weight of the fruit. It may be removed from the winery with a fairly large amount of sugar still remaining, with little sugar, with a little alcohol, or with neither, according to the type of operation of the fermenting room. Indeed, in wineries where pomace stills are used, no pressing is done, and the pomace comes out as a distillery slop, whereas in a winery that produces white wine and that has no still, the pressed pomace may have considerable sugar content. Pomace piles are unsightly and unsanitary. They rapidly acetify, draw flies, and contaminate the winery (fig. 20).

According to Jacob and Proebsting,[80] California pomaces contain 1½ to 2½ per cent nitrogen, about ½ per cent phosphorus, and 1½ to 2½ per cent potassium on a dry-weight basis; also 35 to 70 per cent water, according to the method of pressing and on other considerations. This material has therefore about the same value as corral manure for fer-

[78] General references on this subject are listed on page 137.

[79] Rabak, F., and J. H. Shrader. Commercial utilization of grape pomace and stems from the grape juice industry. U. S. Dept. Agr. Dept. Bul. 952:1–24. 1921.

[80] Jacob, H. E., and E. L. Proebsting. Grape pomace as a winery and orchard fertilizer. Wines and Vines 18(10):22–23. 1937.

tilizer, but appears to act more slowly. On the basis of its nitrogen content, pomace for vineyard and orchard fertilization is worth somewhat less than $2.00 a ton at the winery. Experiments show marked increases in nitrogen in the soil after the use of pomace. Beet lime, and the like, are sometimes mixed with the pomace as it comes from the press. This practice, however, does not increase the value of the pomace for soils not deficient in lime; lime-treated pomace does not differ, in its effect on the soil, from untreated pomace. It may have some value as a sanitation measure, if it prevents the pomace pile from becoming vinegar sour.

A recent report[81] shows that pomace, because of its high fiber content and low nutrient content, is of doubtful value, whether ground or not, as a feed for producing dairy cows. Grape meals appear to have one-third the food value of barley, one-half that of alfalfa hay, and considerably less than that of wheat straw. Where considerable sugar remains in the pomace, it would, of course, have a greater value.

Rabak[82] has also studied the recovery of the seeds for oil from pomace. The process involves drying, disintegration, sifting, grinding, and pressing. He obtained about 11 to 12 per cent oil from dried seeds of eastern grapes. The commercial utilization of seeds, so far seldom attempted in California from winery pomace, would depend on the sales value of grape-seed oil in competition with similar types of oils.

The tannin in grape seeds may be extracted, purified, and sold as grape tannin. Because of the demand for tannin this operation is successfully conducted in Australia. The coloring matter and tannin present in dark-red pomace may be extracted with high-proof spirits and sold as pomace extract. A supply of dark-red pomace, such as that of Salvador grapes, is necessary for the economical production of pomace extract.

CREAM OF TARTAR

At present, the production of tartrates from California crudes is limited. Many European wineries save all their pomace, lees, and distillery slop and regularly scrape their tanks in order to recover the cream of tartar. The pomace may be extracted with hot water, and the cream of tartar allowed to crystallize out on cooling. The lees from the first racking are sometimes sold directly to cream-of-tartar plants. The distillery slop also contains tartar, recoverable by precipitation with lime or gypsum. The precipitate from wines during artificial chilling also constitutes an important tartrate residue.

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[81] Folger, Arthur. The digestibility of ground prunes, winery pomace, avocado meal, asparagus butts, and fenugreek meal. California Agr. Exp. Sta. Bul. 635:1–11. 1940.

[82] Rabak, F. The utilization of waste raisin seeds. U. S. Dept. Agr. Bur. Plant Industry Bul. 276:1–36. 1913.

SPIRITS

High-proof spirits or brandy obtained from pomace or lees is the most widely produced winery by-product. The pomace and lees may be distilled directly, or the pomace may be washed, and the liquid used for distilling material.

STABILIZATION OF WINE[83]

APPEARANCE

Haziness or cloudiness and the presence of sediment indicate to many consumers a defective product, although such a wine may be fundamentally sound and, except for the cloudiness, of excellent quality. When consumers learn how to store wine, it need not be stabilized to withstand extremes of temperature and exposure to light and air.

Cloudiness or the presence of a sediment is, however, under certain conditions, a good indication of spoilage. Clouding may result from the growth and activity of bacteria, yeasts, and molds; from the introduction of metallic impurities, particularly iron, calcium, and tin salts; from the formation and precipitation of insoluble oxidized tannins, coloring matter, or similar products; from the coagulation by heat or cold of certain colloids, either originally present or introduced during clarification; from substances such as cream of tartar, precipitated by exposure to low temperature; and from other factors.

BACTERIAL SPOILAGE

The bacteria responsible for the spoilage of wine are widely distributed in nature and are present in practically all wineries. Their development in wines is restricted by the method of fermenting, storing, and handling the wine and by its composition. The high acidity of dry table wines, their alcohol, their low content of fermentable sugar, their low content of nitrogenous matters and other nutrient elements, and the presence of free sulfur dioxide, all restrict the development of bacteria. Immunity to disease can be increased by cool and complete fermentation, prompt racking, and balancing a must deficient in acid. Many of the acid- and alcohol-tolerant organisms that can develop in wine do not require oxygen for growth, whereas others do. The most serious spoilage is caused by the former, the so-called "anaerobes."

Lactic Acid Bacteria.—The most widely distributed acid-tolerant organisms responsible for the spoilage of wine are Gram-positive, lactic-acid-producing bacteria, both rod and spherical forms.

[83] General references on this subject are listed on page 137.

The presence of lactic acid bacteria in suspension often causes a silky cloudy appearance and streaming as the wine is shaken. This phenomenon is due to the alignment of the bacteria in chains and is caused by any rod-shaped bacterium longer than it is wide. Accompanying the growth of these organisms is the production of an objectionable mousy flavor, the clouding or hazing of wine, and the formation of abnormal flocculents and deposits.

Two main groups of rod-shaped *Lactobacillus* are recognized by Bergey and his associates.[84] One produces only traces of by-products other than lactic acid; the other, considerable amounts of such by-products—

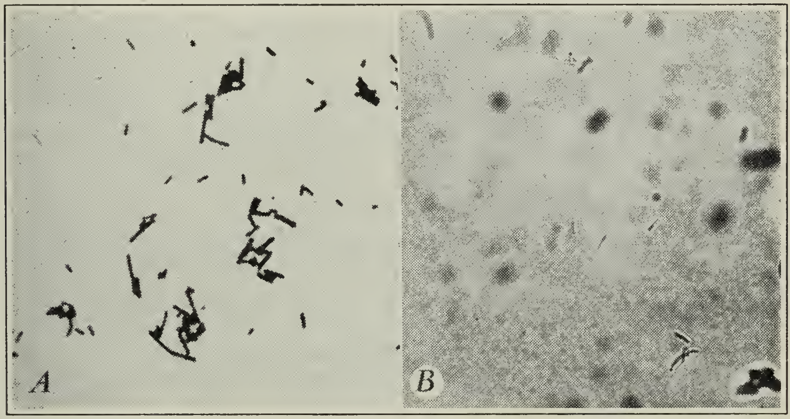

Fig. 21.—Bacteria causing spoiling of table wines: *A*, a pure culture of *Lactobacillus hilgardii* (× 750), Gram stains of cells from 2-day culture grown at 91.4° Fahrenheit; *B*, bacteria in a typical wine sediment (× 750). (Material prepared by H. C. Douglas.)

for example, carbon dioxide gas, alcohol, acetic acid, and mannitol, from levulose.

The spherical, or coccus, form of lactic acid bacteria (classified as *Leuconostoc*) produces carbon dioxide gas, lactic acid, acetic acid, and ethyl alcohol, from dextrose; from levulose, mannitol in addition.

The gas-producing types, both *Leuconostoc* and *Lactobacillus* species, are often called "heterofermentative;" the non-gas-producing types, "homofermentative." The former have been found in wines more often than the latter. Many of the lactic acid bacteria may act upon glycerin and fixed acids (tartaric, malic, succinic) as well as upon sugar.

In certain Rhine wines of high malic acid content, the growth of *Lactobacillus* species capable of converting malic acid into lactic acid is encouraged. Under the usual California conditions, none of these

[84] Bergey, David H., Robert S. Breed, E. G. D. Murray, and A. Parker Hitchens. Bergey's manual of determinative bacteriology. 5th ed. *Acetobacter* sp., p. 222–32; *Lactobacillus* sp., p. 315-78. The Wiliams and Wilkins Co., Baltimore, Md. 1939.

bacteria are desirable. The characteristics of an undesirable *Lactobacillus* (fig. 21) isolated from California wine are as follows:

Morphology:

General—nonmotile, nonsporulating rods occurring singly and in pairs or in short chains of 3 or 4 cells

Size—0.9 × 4.5–6.5μ

Stain—readily; Gram-positive

Growth in liquid media—in diluted grape juice or in diluted sweet fortified wine growth is abundant in 48 to 72 hours at 86–92° F; sediment pulverulent and moderately abundant; undulating or silky cloudiness

Growth in solid media—growth poor; colonies punctiform, white, glistening edges entire; in agar shake cultures, small colonies develop uniformly throughout medium, many being lens-shaped

Biochemistry:

Carbohydrate utilization—levulose, dextrose, and xylose fermented with production of acid and some gas; no fermentation in arabinose, mannose, mannite, glycerin, lactose, sucrose, galactose, raffinose, and dextrin

End-products—levulose converted chiefly into lactic and acetic acid, no mannite formed[85]

pH—optimum pH about 6, growth range pH 3.0–7.6

Temperature—optimum range 88–99° F; very scanty growth at 104°, none at 120°

Oxygen tolerance—after isolation growth obtained both in presence and absence of oxygen

Alcohol tolerance—in sweetened wine slight growth occurred at 18 per cent alcohol in 2 months, at 16.2 per cent in 1 month

SO_2 tolerance—75 p.p.m. of SO_2 prevented growth in sweetened wine of 10 per cent alcohol content

Tannin tolerance—0.2 per cent tannin permitted undiminished growth and even in 0.4 per cent growth good

Destruction by heat—10 minutes at 135° F, 1 minute at 145°, in grape juice

Destruction by SO_2—50 p.p.m. in 20 days; 100 p.p.m. in 13 days; 200 p.p.m. in 7 days[86]

The type of product formed and the particular manifestation of disease depend on the strain of the organism and the character of the wine. A common condition in dry red table wines is tartaric fermentation (referred to as *tourne* in French literature), a disease characterized by loss of tartrates, increase in volatile acidity, decrease in fixed acidity, and increase in pH value. Other types of spoilage are characterized by loss of sugar, increase in both fixed and volatile acidity, and decrease in pH value. Diseased wines have been differentiated into various classes according to the relative amounts of lactic acid and volatile acid produced, since these constituents often serve to distinguish the types of organisms involved: for example, little lactic acid and little volatile

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[85] Strains subsequently isolated by Douglas formed gas and produced mannite.

[86] From: Douglas, H. C., and W. V. Cruess. A *Lactobacillus* from California wine. *Lactobacillus hilgardii*. Food Research 1:113–19. 1936.

acid; much lactic acid and little volatile acid; little lactic acid and much volatile acid; much lactic acid and much volatile acid. The bacterial diseases which have been recognized in European dry wines are described briefly in table 21.

Yeasts.—Aerobic, oxidative, alcohol-destroying yeasts often grow as films on wines of low alcohol content exposed to air. These organisms, usually strains of *Pichia, Debaryomyces,* or *Mycoderma,* are not very tolerant of alcohol and develop only on the surface in contact with air.

Spoiling of California wines by film-forming yeasts is rare because of their alcohol content and the wide use of sulfur dioxide to which these organisms are particularly sensitive. Certain yeasts produce coarsely granular deposits in dry white wines. Species of *Pichia, Saccharomyces,* or *Zygosaccharomyces,* may cause clouding of natural sweet wines low in free sulfur dioxide content. Pasteurization after bottling is the preferred method of controlling such spoilage.

Acetic Acid Bacteria.—Several species of *Acetobacter* that oxidize the alcohol of the wine to acetic acid often occur in wine. Wines high in alcohol are less liable to acetic fermentation than those low in alcohol content. The growth of these bacteria may be checked by the addition of about 1 ounce of sulfur dioxide per 100 gallons, or by pasteurization.

WINE DISORDERS CAUSED BY OXIDATION OR REDUCTION

The presence of excessive amounts of metallic impurities (chiefly iron and copper salts) or overoxidation may produce various types of hazes and sediments. Overoxidation causes the oxidized products of tannin and of coloring matter to be precipitated. Aldehyde formation also occurs and not only gives the wine unpleasant flavors but also causes the formation of insoluble complexes of aldehyde and coloring matter, which settle out. The formation of insoluble complexes of metals on exposure of wine to air is often referred to as "casse."

Iron Clouds.—The presence of iron in white wine often occasions the clouding of them after an aeration, although it is by no means the only cause. The formation of iron clouds depends upon a number of factors, especially the concentration of iron, the nature of the predominating acid and its concentration, the pH, the oxidation-reduction potential, and the concentration of phosphates or tannins. Unless the other conditions are proper for their formation, iron clouds will not occur even in the presence of fairly high concentrations of iron.

Dissolved iron in wine can exist in several different forms, according to the physical and chemical constitution of the wine. Under normal conditions of vinification, the major portion of the iron is present in the ferrous (Fe^{++}) state, the proportion depending upon the amount

TABLE 21

BACTERIAL DISEASES OF WINE AND THEIR CAUSATIVE AGENTS*

Disease	Appearance of wine	Changes in flavor and composition of wine	Causative organisms	Physiological properties
Wine flower	Chalky, fragile, white film on surface if exposed to air, slight haziness, and considerable deposit	Decrease in alcohol, and total acid content; increase in acetaldehyde, giving the wine an objectionable vapid oxidized taste	Aerobic yeasts, particularly *Mycoderma vini*, elongated branching asporogenous cells, 3–10×2–4μ	Oxidize alcohol to carbon dioxide and water, do not attack tartaric very much and citric not at all, but destroy acetic acid and glycerin
Acetic tinge (acescensce)	Translucent, adhesive film, or uniform clouding with deposit, according to type of organism	Decrease in alcohol and sugar; increase in acetic acid, acetaldehyde, ethyl acetate, and fixed acids, giving wine a characteristic acescent, or vinegary, taste	*Acetobacter ascendens, A. viniacetati, A. xylinoides, A. orteanse, A. xylinum;* short rods occurring singly, in pairs, or in chains, either free or surrounded by a zöogleal sheath; nonmotile; usually ½×1μ	Oxidize alcohol to acetic acid, and ferment sugars to acids and alcohols
Tartaric fermentation (tourne)	Haziness with slow evolution of carbon dioxide gas; on slight agitation there appear silky streamers with iridescent reflection which move slowly through the liquid	Decrease in tartrate and sugar content; increase in acetic acid, lactic acid, propionic acid, carbon dioxide, and ammonia, giving wine a sour odor and insipid and "mousy" taste	*Bacterium tartarophtorum;* long thin rods in early stages and curved rods in older cultures; ½-2×2–5μ	One strain acts on both tartartes and glycerin, another only on tartaric acid (apparently these are heterofermentative lactic bacteria)
Mannitic fermentation	Uniform clouding with deposition of mannite and bacterial cells; very little gas formation but wine becomes appreciably viscous	Increase in extract content owing to formation of mannite and glycerin, giving a sweet-sour taste	*Bacterium mannitopoeum*, rod shaped, 0.7×1.3μ	Ferment levulose to mannite, lactic acid, acetic acid, and carbon dioxide; ferment dextrose to lactic acid, acetic acid and carbon dioxide; attacks xylose, arabinose and citrate
Bitterness or bitter fermentation	Haziness; loss in color and precipitation of tannins and coloring matters	Decrease in reducing sugar, tartrates, and glycerin; increase in total and volatile acidity, and ammonia; butyric acid is claimed to occur, bitter and disagreeably acid taste	Similar to that involved in tartaric fermentation	Convert tartrate and glycerin in solution into lactic and acetic acids and some carbon dioxide

TABLE 21—*Concluded*

"Oiliness or fattiness"	Oily appearance, wine pouring in a viscous stream, slow evolution of gas, uniform turbidity, deposits	Decrease in sugar; increase in total and volatile acidity; mannite, acetic acid, lactic acid, glycerin, alcohol, and gum formed	*Bacterium gracile;* small rod-shaped organisms, 0.4×0.6μ	Ferment levulose to mannite, lactic acid, acetic acid, and carbon dioxide; do not decompose xylose; convert malic acid into lactic acid and carbon dioxide
Lactic	Uniform turbidity or deposit with growth at bottom only; slight gas evolution	Decrease in sugar; increase in volatile and fixed acids; "mousy," or lactic, taste	*Micrococcus variococcus*, *M. acidovorax*, and *M. malolacticus*, coccus forms, 0.5–0.7×0.7–1.5μ, singly, as diplococci, or tetracocci; *Bacterium Gayoni* and *Bact. intermedium*, rod-shaped bacteria 0.7–1.3μ, singly or in chains	Ferment levulose to lactic acid, acetic acid, carbon dioxide, and mannite; ferment dextrose to lactic acid, acetic acid, and carbon dioxide; some species (*M. malolacticus* particularly) convert malic acid to acetic acid and carbon dioxide

* Description of organisms taken from:

Müller-Thurgau, H., and A. Osterwalder. Die Bakterien im Wein und Obstwein und die dadurch verursachten Veränderungen. Centbl. f. Bakt., Parasitenk. u. Infektionskrank., Abt. II, **36**:129-339. 1913.

Müller-Thurgau, H., and A. Osterwalder. Weitere Beitrage zur Kenntnis der Mannitbakterien im Wein. Centbl. f. Bakt., Parasitenk. u. Infektionskrank., Abt. II, **48**:1-35. 1917.

Müller-Thurgau, H., and A. Osterwalder. Ueber die durch Bakterien verursachten Zersetzung von Weinsäure und Glyzerin im Wein. Landw. Jahrb. der Schweiz **33**:313-61. 1919.

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For more recent description and classification of the causative organisms see:

Bergey, David H., Robert S. Breed, E. G. D. Murray, and A. Parker Hitchens. Bergey's manual of determinative bacteriology. 5th ed. p. 222-32, 315-78. The Williams and Wilkins Co., Baltimore, Md. 1939.

of oxygen dissolved by the wine. When the quantity of oxygen dissolved is small in comparison with the potential content of reducing matters, a reduction of the ferric iron to the ferrous form will usually occur in storage. These two forms of iron exist both as free ions or as soluble complexes with constituents such as citrates. Under certain conditions, however, such as low acidity and the presence of considerable tannin or phosphate, the ferric ions formed during exposure of the wine to air may combine with the tannins or the phosphates to form insoluble, usually colloidal, ferric complexes. The white ferric phosphate casse occurs only in the range of pH 2.9–3.6. Many California wines are of higher pH. Ferric-tannate casse, rare here and found only after tannin has been added, forms an inky-blue cloud and later a blue deposit. If the concentrations of dissolved iron and tannin or phosphate are large enough to form an appreciable amount of these ferric complexes when the wine is exposed to oxidative conditions, clouding will eventually occur. The cloud formed results from the agglomeration of the colloidal ferric complexes to particles of visible size.

The ferric-phosphate casse can usually be controlled by the addition of citric acid at the rate of 1 pound per 1,000 gallons of wine. The removal of excess iron from the wine by a variety of means will prevent the formation of iron casse.[87] In several European countries, potassium ferrocyanide has been used under government supervision to remove excess iron from wines. When used in excessive amounts it may be dangerous to health.

Copper Deposits.—In sulfited white wines containing over 0.5–0.8 parts per million of copper and stored in sealed containers, a reddish-brown deposit will form. This deposit occurs only in the absence of oxygen and ferric iron and redissolves readily upon exposure to oxygen. Its formation is accelerated by light and heat. Essentially it consists of a colloidal cupric sulfide. The excess copper responsible for this condition can be removed by treatment with a sulfide or potassium ferrocyanide. A better plan, however, is to prevent the condition from arising by avoiding contamination with copper.[88] A comparison of the behavior of wines susceptible to white casse and to copper casse is given in table 22.

Oxidasic Casse.—Oxidasic casse is characterized by clouding and changes of color on exposure to air, red wines turning brown and white wines becoming yellow. These changes are caused by an enzyme known as oxidase, normally present in small quantities in sound grapes and in abnormally high quantities in moldy ones. A wine may be protected

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[87] Ribéreau-Gayon, J. Collage bleu. Traitement des vins par les ferrocyanure. 42 p. Librairie Delmas, Bordeaux. 1935.

[88] Ribéreau-Gayon, J. Le cuivre des moûts et des vins. Annales des Falsifications et des Fraudes 28:1–12. 1935.

from the action of this enzyme by the use of sufficient sulfur dioxide or metabisulfite; or by destroying the oxidase by flash pasteurization at 158°–185° Fahrenheit, according to the condition of the wine. This form of casse, though less common in America than in France, may be expected in any wines made from moldy grapes.

TABLE 22

The Behavior of Wines Susceptible to Clouding by Iron Casse and by Copper Casse

Points compared	Type of turbidity and its behavior	
	White iron casse	Copper casse
Essential nature:		
Appearance	A uniform white turbidity appearing after exposure of wine to air	A white haze appearing in wines stored in the absence of air; later a reddish-brown sediment
Causes	Colloidal ferric phosphate; oxidation of free ferrous ions, in presence of excess phosphate, and formation of suspended aggregates of ferric phosphate which eventually settle out and form a white deposit	Colloidal cupric sulfide; a complex reduction of cupric ions and sulfite, involving reduction of other metals; does not happen in presence of free ferric ions; cupric sulfide forms first as a white haze which later becomes reddish in color and finally deposits as a reddish-brown sediment
Action of various physical and chemical agents:		
Air	Turbidity appears after exposure to air; wines that become turbid on oxidation often clear when stored in absence of air, owing to deposition of ferric phosphate	Turbidity disappears on exposure to air and appears in its absence; the disappearance of turbidity after oxidation may be accompanied by slight sediment formation
Light	Light hinders the appearance of turbidity, and decreases its intensity	Light hastens the appearance of turbidity and increases its intensity
Heat	Hinders turbidity	Hastens turbidity
Hydrogen peroxide and similar strong oxidizing agents	Turbidity appears immediately after addition of H_2O_2	Turbidity, if present, disappears immediately
Sulfur dioxide and similar reducing agents	Prevent turbidity	Hasten and increase turbidity
pH	Turbidity appears only in range of pH 2.9 to 3.6	———
Citric acid	Specific inhibitor and preventative agent even in small amounts	No effect unless added in excessive quantities
Precautionary treatments	Avoid contamination of wine with phosphates, iron, and copper salts, and oxidation	Avoid contamination of wine with iron and copper salts, and use of excessive amounts of sulfur dioxide

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INDEX

acetaldehyde, 30, 33, 34, 90, 123, 124
acetic acid, 10, 30, 118, 124, 125; bacteria, 10, 35, 37, 39, 124; esterification of, 90; in musts, 39; retarding influence on fermentation, 32
Acetobacter, 39, 121, 123, 124; effect of temperature on, 38
acidity, 10, 11, 12, 15, 22, 23, 32, 33, 68, 76, 84, 88, 120, 122–125; amelioration of, 15, 35, 36, 81; analyses, 106; changes during maturation, 18, 25; effect on fermentation, 35; in various wine types, 13, 114, 115, 116; influence on bacteria, 35; influence of climate on, 24; limits, 15; of pink wines, 77; of sparkling wines, 99; of white wines, 78, 85; relation to pH, 19, 20; *see also* acetic, citric, lactic, malic, propionic, succinic, and tartaric acids
acknowledgment, 128
acreage, 4
aeration, as a cause of cloudiness, 109; during bottling, 109; during fermentation, 31, 33, 72; influence on alcohol loss, 31, 33; influence on rate of aging, 90, 91; influence on white wines, 81, 82
aging, 10, 55, 76, 82–84, 87–88, 89–91; definition, 89; of champagne, 104; overaging, 76, 84, 91, 92; time of, 92, 109
agrafe, 101, 102
albumen, 92
alcohol, 9, 12, 25, 76, 87, 120; action of bacteria on, 124, 125; amyl, 32; analyses, 106; ethyl, 30, 90; higher, 30, 32; in aging, 90; in various types of wines, 13, 15, 77, 99, 114, 115, 116; influence on fermentation, 33; limits, 15; loss during centrifuging, 96; propyl, 32; yield, 30
aldehydes, *see* acetaldehyde
Aleatico, 28, 88, 117
Algeria, acid of musts, 18, 19; *lessivage* system in, 71; pink wines in, 77; pressing in, 85; production, 8; use of tannin in, 37; winery design in, 54, 60
Alicante Bouschet, 29, 45; acreage of, 4; color of, 20, 26; composition, 20, 24; ripening changes in, 19
Allegheny C, 58
alloy 18.8, 58
alum, for outside of cooperage, 64
aluminum, 22; alloy, 58
amino acids, in musts, 20
amelioration, *see* balancing
ammonia, in musts, 20
ammonium phosphate, addition to musts, 37
amyl alcohol, 32
anaerobes, 120
analyses, 74, 88, 106–108; alcohol, 106; extract, 107; reducing sugars, 107; sulfur dioxide, 108; tannin and coloring matter, 107; total acid, 106; volatile acid, 106
Angelica, 112
anthocyanin, 20, 22; *see also* color
Aramon, for pink wines, 76; for red wines, 29
aroma, *see* bouquet
arsenic, 21
ascorbic acid, 21
ash content, of must, 21, 22
astringency, 10, 113, 116
Australia, tannin production in, 119; use of tannin in, 37

bacteria, 29, 49; acetic acid, 34, 35, 123; action of sulfur dioxide on, 40, 76, 83, 88; clouding due to, 73, 83, 120; detection, 105; from corks, 111; in stuck wines, 37; in the winery, 74, 76, 88, 96, 110; lactic acid, 34, 35, 37, 120, 123; relation to flavor, 34
Bacterium species, 124, 125
balancing, musts, 35, 36, 37, 68, 81; of champagne stock, 99; wines, 108, 109
Balling, for natural sweet wines, 85; for pink wines, 77; for red wines, 66; for sparkling wines, 99; for white wines, 78; hydrometer, 23; influence of environment on, 24; no relation to dryness, 74, 86; ratio to acid, 19, 20; relation to color extraction, 70; readings, 19, 20, 23, 24, 25, 33, 66, 69
Barbera, 28; acidity, 26; composition, 20; *see also* California Barbera
barrels, 57, 59; *see also* containers
Beclan, 29
beeswax, 112
beet lime, 119
bentonite, 92, 93
bitter fermentation, 124
Black Hamburg, color, 77
Blarez ratio, for determination of added sugar, 11; for determination of dilution, 12
blending, musts, 29, 67, 108; wines, 108, 109
Blue Portuguese, 29
body, 87; heavy, 10, 76, 77, 112; light, 10, 75, 76, 83; of various wine types, 116; relation of extract content to, 10; relation of glycerin content to, 11
Bonny Doon (Santa Cruz County), climate, 23; composition and musts of, 25
bottles, 96; for California champagne, 100; for California red Chianti, 116; inspection, 100, 110; stacking of, 101; types, 109, 110
bottling, 84, 88; procedure, 109, 110; purpose, 109; sterile, 96
Botrytis cinerea, 21, 84
Bordeaux, acidity of musts, 20; red wines, 113; white wines, 84
bouquet and aroma, 12, 22, 34, 84, 89, 101, 105; effect of low temperature fermentation on, 48, 101
brandy, 8, 9, 87, 102, 120
brass, 97
Brix hydrometer, 23, 107
brut, for champagne labels, 117
bungs, 73, 81; fermentation, 73, 89
Burger, 29, 98; acreage, 4; composition, 24
Burgundy, 14, 45; composition, 13; varieties for, 29; yeasts, 45, 47; *see also* California Burgundy
butts, 59, 60
2,3-butylene glycol, 30

Cabernet Sauvignon, composition, 20, 24; quality of wine, 12, 27, 28; *see also* California Cabernet
calcium, 21, 22; pickup, 55, 63, 94, 95, 120
California, Barbera, 28, 113, 114; Burgundy, 13, 112, 113, 114; Cabernet, 28, 113, 114; Central Coast Counties Dry Wine, 15; Chablis, 13, 113, 114; Chateau, 85, 115, 117; claret, 13, 113, 114; dry sauterne, 115, 117; Golden Chasselas, 28, 115; hock, 113, 114, 116; Moselle, 113, 114, 116; red Chianti, 13, 113, 114; Riesling, 13, 28, 113, 114; Sauvignon blanc, 28, 115, 116; sweet sauterne, 13, 115, 117; Traminer, 28, 115, 116; white Chianti, 115, 116; Zinfadel, 28, 113, 114
cap, in red-wine fermentation, 69, 70, 71
capping, 103
capsuling, 104, 112
carbon dioxide, 29, 30, 33, 89, 90, 97, 122, 124, 125; in sparkling wines, 99, 100; in storage containers, 73, 83; in the *lessivage* system, 71; in white wines, 84; influence on fermentation, 33

carbonated wines, 97, 102, 117; material for, 97; procedure in making, 103
Carignane, 27, 98; acreage, 4; color, 26; composition, 20, 24
casein, 92, 93
casse, 37, 109, 123, 126, 127; copper, 126; iron, 123; oxidasic, 126, 127
casks, 59, 60, 84; *see also* containers
catechol, 21
cellar, 53, 54, 63, 73, 75, 76, 83, 92; services for, 55; size, 55; temperature of, 53, 89
centrifuging, must, 80; wine, 96
Chablis, 14; color of, 11; composition, 13; *see also* California Chablis
champagne, 14, 97–104, 117; aging, 104; bottling, 101; bulk process, 97, 103; capping, 104; composition of stock, 99; corking, 101, 103, 104; depletion of nutrient elements, 39; disgorging, 101; fermentation, 99, 103; fining, 99; France, 81, 99; preparation of material for, 98; varieties for, 98; yeast, 30, 47, 100
Charbono, 29
charcoal, 100
Charmat process, 97, 103
Chardonnay, 28, 98, 113; flavor, 27
Chasselas doré, 28; composition, 20
Chauché noir, 29
Chianti, 14; composition, 13; *see also* California red and white Chianti
chloride, 15, 21
chlorophyll, 20, 22
citric acid, 15, 22, 32, 124; addition to must, 36; addition to wines, 100, 126, 127
claret, 14, 27; composition, 13; *see also* California claret
clarification, 73, 77, 83, 84, 87, 89, 92–96, 99, 101, 109
climate, 16, 18; influence on composition, 23
cloudiness, 73, 79, 80, 82, 83, 94, 104, 112, 120, 123–127; after blending, 109; measurement of, 95
colloidal matters, 79, 80, 83, 84, 86, 92, 126, 127; precipitation by cold, 120; precipitation by heat, 97, 120
Colombard, *see* Sauvignon vert
color, changes in aging, 81, 89, 92; extraction of, 70, 72; in grapes, 20, 22, 77; in various types of wines, 112, 114; in wines, 4, 11, 25, 69, 70, 72, 78, 79, 88, 99, 104, 105, 126, 127; influence of climate, 24, 26; influence of charcoal, 100; of white wines, 78, 79, 99; of white wines from red grapes, 81
composition, of musts, 16, 19–26; of wines, 9–15, 25, 106
Concord, 45
concrete, calcium from, 55, 63; closed tanks, 71; for floors, 56; for tanks and vats, 54, 56, 60, 63, 88
consumption of wine, in France, 8; in Italy, 8; in the United States, 5, 6
containers, concrete, 54, 61, 63, 71; conditioning of, 63–65; fermentation, 54, 60, 61, 62, 86; filling of, 75, 82; influence on aging, 75, 76, 83, 91, 92; oak, 59, 60; redwood, 59, 61, 69; sterile, 96; storage, 54, 64, 73; types, 59, 60; used, 64
contamination, 64, 65, 67, 73, 82, 83, 88, 91, 110, 126
cooling coils, 52, 62, 70, 71, 72
cooperage, *see* containers
copper, casse, 97, 126, 127; cupric sulfide, 126; from equipment, 55, 59, 97; in musts, 21, 37; in sparkling wines, 98–99
corking, 111
corks, 111; for sparkling wine, 100–101, 103; leakage around, 101, 104; preparation of, 111; size, 111; sterile, for wine, 95, 96, 111; *tirage*, 100–101.
corrosion-resistant metals, 55, 56, 58, 97, 103, 110
cream of tartar, *see* tartrates
crusher, 54, 57, 58, 59, 65, 66, 67, 78; materials for, 55, 58; care of, 65
crushing, 17; red wine grapes, 67; white wine grapes, 78, 85

Davis, climate, 23; composition of musts and wines of, 25
Debaryomyces, 123
Delano, color content of grapes of, 26
demi doux, for champagne labels, 117
dessert wines, 3, 9; must requirements for, 23; production of, 7, 8
detergents, 110
dextrose, 11, 18, 22, 30, 124, 125; analyses, 107; ratio to levulose, 18
disgorging, 100, 101–102
distilling material, 63, 72, 73, 74, 79, 86, 120
dosage, 103
dry, for champagne labels, 117
Durimetl, 58
Duriron, 58

Ebon, 61 (footnote)
ebullioscope, 106
egg albumen, 92
environment, effect on color, 21, 23–26; effect on composition, 19, 22–26
enzymatic clarification, 18
enzymes, 18, 21, 29, 84, 91, 126; definition, 30; source, 21, 31; tolerance for alcohol, 32
esters, 30, 34, 90; types found, 90; esterification process, 89, 90
ethyl acetate, 10, 124
ethyl alcohol, *see* alcohol
extract, 10, 12, 22, 34, 79, 86; analyses, 106, 107; effect on alcohol determination, 106; in various types of wines, 13, 113, 114, 115, 116

fats, in musts, 21
fattiness, disease, 125
fermentation, after, 89; by-products, 30, 33; definition, 29; effect of acidity on, 31, 32, 35; effect of aeration on, 31, 33; effect of sugar on, 31, 33; effect of temperature on, 31; effect of yeasts on, 31; in bottles, 99, 101; in closed containers, 103; low-temperature, 39, 48, 51, 52, 89, 101; products, 30; propagation of, 35–52; of natural sweet wines, 86, 87; of red grapes, 68, 70, 71; of white musts, 81; record of, 61, 69
fermenters, 50, 54, 60, 61, 62, 89; closed, 60, 70, 71; cooling of, 50, 51; for natural sweet wines, 86; for red wines, 68; for white wines, 81, 82; materials for, 59–61; preparation of, 61, 63, 64
fermenting room, 53, 54, 55; floors, 56; separation of red and white, 53; services for, 56; size, 55, 66; sumps in, 55; temperature of, 53
ferric phosphate, casse due to, 37, 126, 127
fillers, 111
filling, 75, 82, 109, 110
filters, asbestos pad, 95; bulk, 87, 94; carbon-candle, 95; filter presses, 94, 95; leaf-type, 95; maintenance of, 65; polishing, 94, 95; porcelain-candle, 95; pulp, 94; sterilizing, 94, 95
filtration, 14, 83, 84, 94, 109; after blending, 93; after fining, 93; after pasteurizing, 97; of champagne material, 99; of musts, 80, 87
filter aids, 22, 94, 95
fining, 92, 93, 94, 96, 109; after blending, 109; agents, 92, 93; of champagne material, 99; of musts, 80; of natural sweet wines, 88; of white wines, 79, 84
Flame Tokay, color of, 77
flavor, 10, 12, 14, 16, 17, 34, 76, 77, 85, 88, 89, 90, 91, 101, 105, 108, 110; corky, 111; dilution by blending, 109; during disgorging, 102; effect of bentonite on,

93; effect of sulfur dioxide on, 39, 40; from filters, 95; metallic, 105; of various types of wines, 113, 116, 117; rancio, 90
fluosilicic acid, 65
Folle blanche, 29, 98
Food and Drug Administration, 15
France, acidity of musts in, 36; Bordeaux, 20, 84, 113; consumption in, 8; pressing in, 85; production of, 3, 8; use of lactic acid bacteria in, 34; wines of, *see under* various type names, *as* Chablis
Franken Riesling, *see* Sylvaner
free-run juice, 78, 79, 81
Fresia, composition, 20; flavor, 27
Fresno, climate, 23, 25; color content of grapes of, 26; composition of musts and wines, 25
fructose, *see* levulose
furfural, 30
fusel oil, 30

gallic acid, 111
Gamay, 28, 112; flavor, 27; pink wine from, 77
Gautier sum, 12
Gay-Lussac equation, 30
gelatin, 92, 93, 99; influence on color, 92
Germany, 13, 18, 84, 121; use of lactic acid bacteria in, 34, 121
glasses, for tasting, 105
glucose, *see* dextrose
glycerin, 11, 12, 21, 30, 33, 34, 50, 84, 87, 102, 121, 124, 125; for soaking corks, 111
Golden Chasselas, *see* California Golden Chasselas *and* Chasselas doré
gondola trucks, 67
grapes, acreage by varieties, 4; changes in during ripening, 16, 19, 20; composition, 16, 17, 18, 19, 20, 23; concentrate, 15, 87; crushing, 58; drying of, 85; juice yield, 17; late-picked, 23, 81, 85; moldy, 41, 67, 78; physical composition, 16, 78; picking, 66, 67, 78; pulp, 16, 89; second-crop, 67; seeds, 16, 72, 78, 81, 85; skins, 16, 67, 72, 78, 81, 85, 89; sorting, 67; stems, 18, 78, 118; suitability for wine making, 16, 23, 25; transportation, 67, 78; vascular system of, 16; yield of wine, 18
Gray Riesling, 28, 116
Green Hungarian, 29, 98
Grenache, 29; acreage, 4; color, 26, 77
Grignolino, 28, 76; flavor, 27; tannin content of, 10, 77
Guasti, color content of grapes from, 26
gums, 22, 79, 91, 125

Halphen ratio, 12
Hanseniaspora, 46
harvesting, for pink wines, 77; for red wines, 66; for sparkling wines, 98; for white wines, 78, 85; proper stage for, 23; sanitation in, 67, 78; knives and shears, 67
Haut Sauterne, *see* California sweet sauterne
heat exchangers, 52, 96–97; *see also* pasteurization *and* temperature
heterofermentative, 121, 124
hock, 13, 14; *see also* California hock
homofermentative, 120
hoops, care of, 64
hoses, 53, 65
hydrogen peroxide, 64
hydrogen sulfide, from sublimed sulfur, 43; in white wines, 82; odor of, 105
hypochlorite, 64, 65

Inconel, 58
inosite, 18, 22
iron, clouding due to, 120, 123, 126, 127; ferric and ferrous, 123, 126; ferric phosphate, 37, 126, 127; ferric tannate, 126; from equipment, 55, 59, 94, 95, 111; from gondola trucks, 67; in champagne material, 98; in must, 19, 21, 22
isinglass, 92, 93, 99, 109
Italy, Barbera wine, 113; Chianti wines, 13, 113, 116; consumption in, 8; Grignolino wine, 76

Johannisberger Riesling, *see* White Riesling

kegs, 60, 108; *see also* containers
Kleinberger Riesling, 28, 116
Kloeckera, 46
Kloeckeriaspora, 46
knives, for picking, 66

labeling, 14, 112–113, 116–117
lactic acid, 30, 121, 124, 125; bacteria, 14, 34, 35, 37, 120; influence of sulfur dioxide on lactic acid bacteria, 43
Lactobacillus, 121, 122
lead, 21
lecithin, in musts, 20
lees, 74, 81–82, 84, 91, 101, 104, 118, 120; definition, 89
legal restrictions, 14, 15
lessivage system, 71
Leuconostoc, 121
levulose, 11, 18, 22, 30, 124, 125; ratio to dextrose, 18
lime water, for conditioning, 65
linings, 56, 59, 61, 63, 64
linseed oil, 61, 63, 64
liqueur, *tirage*, 100; sweetening, 102–103
Livermore Valley, color content of grapes of, 26
Lodi, color content of grapes of, 26

magnesium, 21, 22
malic acid, 15, 18, 19, 22, 32, 91, 121
Malvasia bianca, 116
manganese, 22
mannite, 124, 125; mannitic fermentation, 124
masking, in champagne bottles, 101
Mataro, 29; acreage, 4; color, 26, 77
maturity, for champagne stock, 99; for natural sweet wines, 85; for picking, 23; for red wines, 66; for white wines, 78; of grapes, 18–24
metaphosphate, for washing bottles, 110
microbiological examination, 74, 83, 105, 120–122, 124, 125
Micrococcus species, 125
microörganisms, *see* acetic acid, bacteria, *Botrytis cinerea*, lactic acid, molds, *and* yeasts
mineral content of musts, 21, 22
Mission, 29; acreage, 4; color, 26, 77; composition, 20
mixed cultures, 34, 46
molds, 15, 29, 41, 67, 78, 109, 120; on corks, 111, 127
Mondeuse, 27, 98
monel metal, 58
Moselle, 14; Riesling from, 13; *see also* California Moselle
mousy flavor, 15, 39, 121, 124, 125
Muscat, 22, 45; of Alexandria, 19, 20, 116; Canelli, 98, 116; flavor, 12, 87, 88; ripening changes in, 19; *see also* Aleatico *and* Malvasia bianca
muselet, 103
must, 15, 17, 18, 24, 29, 54, 58, 80, 81, 85–87, 105; acid content, 18; acetified, 39; buffer capacity, 19; color, 20; composition, 22; lines, materials for, 55, 58, 59, 66, 68; mineral content, 21; *mutéd*, 87; nitrogen content, 20; pumps, 54, 58, 66, 68; sugar content, 18; tannin content, 21, 80; vitamin content, 21
Mycoderma, 123, 124

Napa Valley, 25
natural sweet wines, 84–88; aging, 88, 89; color of, 11; crushing for, 85; glycerin content, 11, 84; procedure for making, 86;

total acid content, 10, 85; use of sulfur dioxide in, 87; *see also* Aleatico, California Chateau, California dry sauterne, California sweet sauterne, *and* sauternes
Nebbiolo, composition, 20; flavor, 27
nitrates, in musts, 20
nitrogen, in musts, 20, 22, 35, 84; relation to classification, 21; relation to nutrition of yeasts, 21; relation to spoilage, 21, 120
nutrients, 32, 35, 39, 87, 89, 120

oak, containers, 56, 57, 59, 62, 63, 91; flavor of, 76, 84, 91
oenidin chloride, 21
oenin chloride, 20
Ohanez, ripening changes in, 19
oiliness, disease, 125
oils, in seeds, 17, 21, 119; neutral, for conditioning, 64
ovals, 57, 60, 62; *see also* containers
oxidase, 21, 84, 126; casse, 126
oxidation, 12, 30, 31, 33, 72, 81, 82, 83, 89, 111; in aging, 90, 91; -reduction potential, 126

Palomino, 29; acreage, 4; composition, 20
pasteurization, 14, 96, 109, 127; bulk, 97; of musts, 80
pectin, 18, 22, 79
pectinase, 21
pentosans, 18, 22
pentoses, 18, 22
peptides, in musts, 20
Petite Sirah, 98, 112; acreage, 4; color, 26; composition, 20; flavor, 27; harvesting, 66
Petite Verdot, 29; ripening changes in, 16
Peverella, flavor, 27
pH, 19, 22, 83, 122; definition, 18; influence of environment on, 23, 24; range for iron casse, 126, 127; relation to titratable acidity, 19, 20
phlobaphanes, 21
phosphate, 21, 35, 37, 99, 123, 126, 127
Pichia, 123
pink wines, 76; color of, 11, 88; production of, 77; varieties for, 77
Pinot blanc, 98; flavor, 27; wine, 28
Pinot noir, 28, 98, 112; composition, 20; flavor, 27; pink wine, 77
pipes, 56, 65; containers, 59, 60
polyhydroxy-benzoic acids, 21
pomace, 17, 52, 54, 62, 72, 79, 85, 86, 118–120; conveyor, 60, 61, 66, 69, 118; extract, 119; feed value, 119; fertilizer value, 118, 119; stills, 118; wines, 15
Portugal, correction of acidity in, 36
potassium, in musts, 21, 22, 35; in wines, 15
potassium ferrocyanide, for removing iron, 126; for removing copper, 126
potassium metabisulfite, *see* sulfur dioxide
potassium permanganate, for conditioning containers, 64
presses, 54, 62; continuous, 62, 73, 79; hydraulic basket, 62, 73, 79, 80; maintenance, 65; materials for, 55, 56; rack-and-cloth, 79
pressing, 17, 73, 77, 79, 81
press wine, 79
pressure gauges, 80, 100
production of wine, in California, 8 in France, 8; in the United States, 5, 7, 8
propionic acid, 124
propyl alcohol, 32
protein, 20, 91
pulp, 16, 89
puncheons, 60, 62; *see also* containers
punching down, 69, 71
pure cultures, 34, 45, 47, 68; *see also* yeasts
purines, in musts, 20

quercetin, 21
quercitrin, 21

racking, 74, 75, 81, 82, 83, 88, 89, 94, 98
racks, for champagne, 101, 102
records, of fermentation, 61, 68, 69
red wines, 66–76; after fermentation, 73; aging, 74, 75, 76; alternative methods for producing, 70–72; color of, 11; definition, 14; extract content of, 10; fermentation of, 68–70; tannin content of, 10; tasting of, 105; types, 13, 28, 112–114; varietal, 27, 28; *see also* Burgundy, California Barbera, California Burgundy, California Cabernet, California claret, California red Chianti, California Zinfandel, claret, *and* Chianti
redwood containers, 48, 59, 61, 69, 94; conditioning of, 63
Refosco, 27
refrigeration, 14, 51, 52, 76, 80, 82, 83, 87, 103
regional effects, on color, 25; on composition, 24, 26
remuage, 102
respiration, effect on alcohol yields, 31
Rhine, composition of Reisling from, 13; wine, 14
Riesling, grapes, 28, 113, 116; wine, 11, 13, 20, 28, 114, 116; *see also* California Riesling, Gray Reisling, Kleinberger Reisling, Wälschriesling, *and* White Riesling
Rkatsateli yeast, 30
Reims, France, 101
Roos ratio, 12
rosé wines, *see pink wines*

Saccharomyces species, 45, 46
Saint Emilion, 29, 98, 116
Saint Macaire, 29
Salvador, 119
San Joaquin Valley, climate, 23, 24, 26
Sangioveto, flavor, 27; in Chianti, 112
sanitation, in bottling, 109; in the winery, 54, 56, 61, 63–66, 69, 74; in picking, 67, 78
Santa Clara Valley, color content of grapes of, 26
Santa Cruz Mountains, color content of grapes of, 26
sauterne, 14, 45, 112; composition, 13; depletion of nutrient elements in making, 39; sugar content of, 10; *see also* California dry sauterne, California sweet sauterne, California Chateau, natural sweet wine, *and* sauternes
Sauternes, 13, 117
Sauvignon blanc, 28, 117; *see also* California Sauvignon blanc
Sauvignon vert, 29, 98; acreage, 4; composition, 24
Schaumwein, 97
Scobicia declives, 64
screw caps, 111
sec, for champagne labels, 117
sediment, *see* lees
seeds, 16, 41, 72, 78, 81, 85; oil from, 16, 21, 119; tannin from, 16, 21, 119
Sekt, 97
Semichon process, 82
Semillon, 28, 29, 117; composition, 24
settling, 80, 86, 94, 99
shears, for picking, 67
skins, 16, 21, 41, 67, 69, 72, 78, 81, 85, 89
soda ash, for conditioning containers, 63, 64; for washing bottles, 110
sodium, 15, 21, 22
Sonoma County, color content of grapes of, 26
sparkling wine, Burgundy, 97, 117; definition, 97; *see also* champagne
spirits, 8, 87, 119, 120
spumante, 97; depletion of nutrient elements from, 39
stainless steel, 58
State of California, Board of Equalization, 14; Department of Agriculture, 14; Department of Public Health, 15

starter, 46–47; *see also* pure culture *and* yeast
statistics, on production and consumption, 5
Steinberg yeast, 30
stemmer, 54, 57, 66, 78; care of, 65; materials for, 58
stemming, 17, 67, 78, 85
stemmy flavors, 77, 78
stems, 16, 17, 21, 59, 78, 118
storage cellar, *see* cellar
stuck wine, 32, 73; procedure for handling, 37, 38
succinic acid, 30, 50, 121
sugar, analyses, 107; for champagne, 100, 102; in musts, 18, 22, 23, 66, 67, 86; in various types of wines, 13, 114, 115, 117; in wines, 9, 73, 74, 88, 102, 103, 120, 124, 125; relation to alcohol yield, 31; tasting of, 105; *see also* dextrose *and* levulose
sulfate, 15, 21
sulfur dioxide, acidifying action, 41, 42; amounts to use, 40, 41; analyses, 108; and copper casse, 126; and concrete tanks, 63; antioxidative action, 42; antiseptic power, 40, 123; clarifying action, 41; combined, 40; dangers in sparkling wines, 98; dissolving action, 41; effect on enzymes, 42, 127; effect on flavor, 39, 40; for empty containers, 64; for natural sweet wines, 87, 88; for pink musts, 77; for red musts, 68; for sterilizing corks, 111; for washing corks, 96, 111; for white musts, 80; for white wines, 83; for red wines, 76; free, 14, 40; in various types of wine, 13; influence on acetic acid bacteria, 39; influence on aldehyde accumulation, 34; influence on aging, 91; influence on color and acidity, 41, 42; influence on fermentation, 43; influence on preservation, 43; limits, 14; liquid, 43; massive doses, 72, 77, 87; odor, 105; procedure for using, 43, 44, 46; sources, 43; specific gravity of solutions of, 44
sulfurous acid, *see* sulfur dioxide
sulfuric acid, 11, 65
sumps, in fermenting rooms, 55, 68
sunburning, 85
Sylvaner, 28, 116; acreage, 4; composition, 20

table wines, 3, 9; bulk quality, 26; must requirements, 23; production of, 7, 8
tank cars, care of, 65
tanks, 59, 62, 68, 71, 75; *see also* containers
tannase, 21
Tannat, 27
tannin, addition to musts, 35, 37; addition to wine, 37, 100, 126; analyses, 107: clouding due to, 120; extraction during fermentation, 72; in fining, 92, 93, 99; in musts, 21, 22, 79, 81; in seeds, 16, 21, 119; in stems, 16, 21, 118; in various types of wines, 13, 114, 115; in wines, 10, 76, 79; influence on rate of aging, 90, 91; influence on microörganisms, 37
tartaric acid, 15, 18, 22, 32, 91, 121, 124; addition of, to must, 36, 81; changes during aging, 36, 91, 92; for washing concrete containers, 61; for washing filter pads, 95; in analytical results, 106
tartaric fermentation, 122, 124
tartrates, 22, 36, 76, 83, 89–92, 109, 119, 124; clouding due to, 120; in stems, 118; recovery, 119; removal, 63, 91, 92; removal, in making sparkling wines, 99, 101
tasting, 74, 102, 104, 108
temperature, amount of cooling needed, 51; amount produced by fermentation, 49, 50; as a cause of "sticking," 49; effect of too low temperatures, 52, 70, 82; effect on alcohol yield, 32, 49; effect on bouquet, 34, 48; effect on fermentation rate, 32; for natural sweet wines, 88; for removing tartrates, 91; for sparkling wine stock, 99, 101; for storage, 91; for the after-fermentation, 89; for white wines, 82; loss from fermenters, 51; procedures and equipment for cooling, 51, 52, 62; record of, 69; reducing, 51; use of heat to extract color, 72
thermometer, 52, 68
tin, clouding due to, 120
tirage bottling, 100
tourne, 14, 122, 124
Traminer, 28; *see also* California Traminer
transportation, of red wine grapes, 67, 68; of white wine grapes, 78, 85
Trebbiano, *see* Saint Emilion
trisodium phosphate, for washing bottles, 110

Ukiah, color content of grapes of, 26
Ugni blanc, *see* Saint Emilion
United States Treasury Department, Basic Permit and Trade Practice Division of the Alcohol Tax Unit of the Bureau of Internal Revenue, 14
urea, addition to musts, 37

Valdepeñas, 27
vats, 59–61, 69; care of, 64; false bottom in, 62
ventilation, 55
vin mousseux, 97
vintage, on labels, 112, 117
vitamin, B, 21; C, 21
Vitis vinifera, 9
volatile acid, 10, 33, 49, 76, 122, 123; analyses, 106; effect of sulfur dioxide in preventing, 42, 123; limits, 14; limits in sparkling wines, 97, 98; state limits, 15; odor, 105; *see also* acetic acid

Wälschriesling, 28, 116
White Reisling, 28, 113, 116; composition, 20
white wines, 78–84; aging, 82; clarification, 83; color of, 11; extract content of, 10; fermentation, 81; making of, 78; red grapes used for, 81; tannin content of, 10; types, 13, 113–116; varietal, 27, 28; *see also* Chablis, California Chablis, California Golden Chasselas, California hock, California Moselle, California Riesling, California white Chianti
wine, definition, 8, 9; *see also* natural sweet wines, pink wines, red wines, sparkling wines, table wines, *and* white wines
wine flower, disease, 124
winery, arrangement, 53, 54; equipment, 55–63; floors and piers, 56; location, 53; materials, 53–55; ventilation, 55; size of, 55
wire cap, for champagne bottles, 104

yeast, 29, 45–47; adaptation to sulfur dioxide, 40; acid tolerance of, 32; alcohol tolerance, 32, 33; for bottle fermentation, 101; Burgundy, 45, 47; champagne, 30, 47, 100, 101, 103; clouding due to, 120, 123; effect of sugars on, 33; flavor formation by, 34, 45; for natural-sweet-wine fermentation, 87; for sparkling-wine fermentation, 100; for white-wine fermentation, 81; from corks, 111; oxygen requirement, 33; Rkatsateli, 30; Steinberg, 30; settling of, 73, 89; wild, 32, 35, 46, 80
yield, of stems, pomace, juice, and wine, 18

Zinfandel grape, acreage, 4; color, 26; composition, 20, 24; harvesting, 66
Zinfandel wine, 28, 112, 113; flavor, 12; pink, 77; *see also* California Zinfandel

15*m*-9,'40(6630)